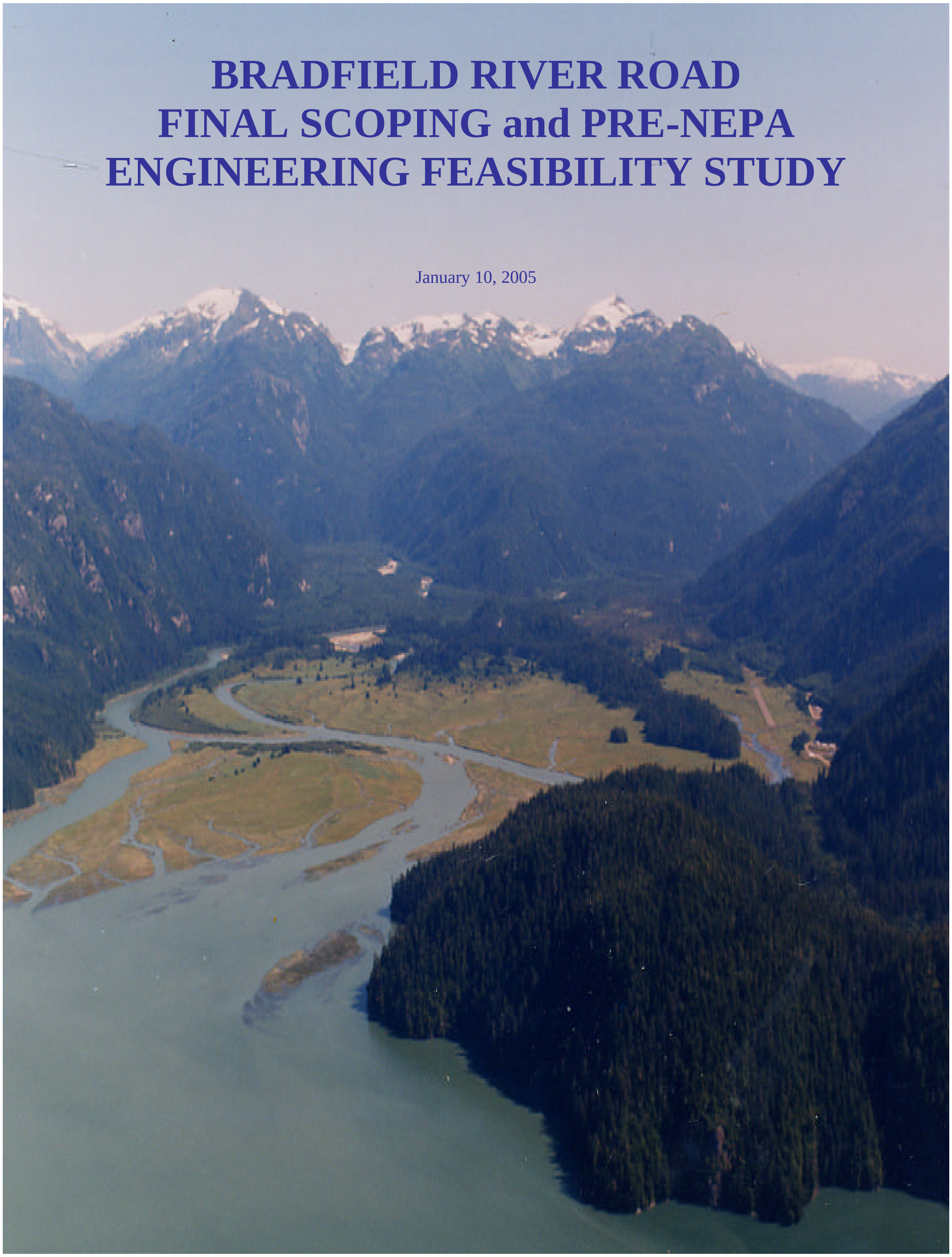
BRADFIELD RIVER ROAD
FINAL SCOPING and PRE-NEPA
ENGINEERING FEASIBILITY STUDY

January 10, 2005



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In cooperation with:

Alaska Department of Transportation and Public Facilities

USDA Forest Service

and

City of Wrangell

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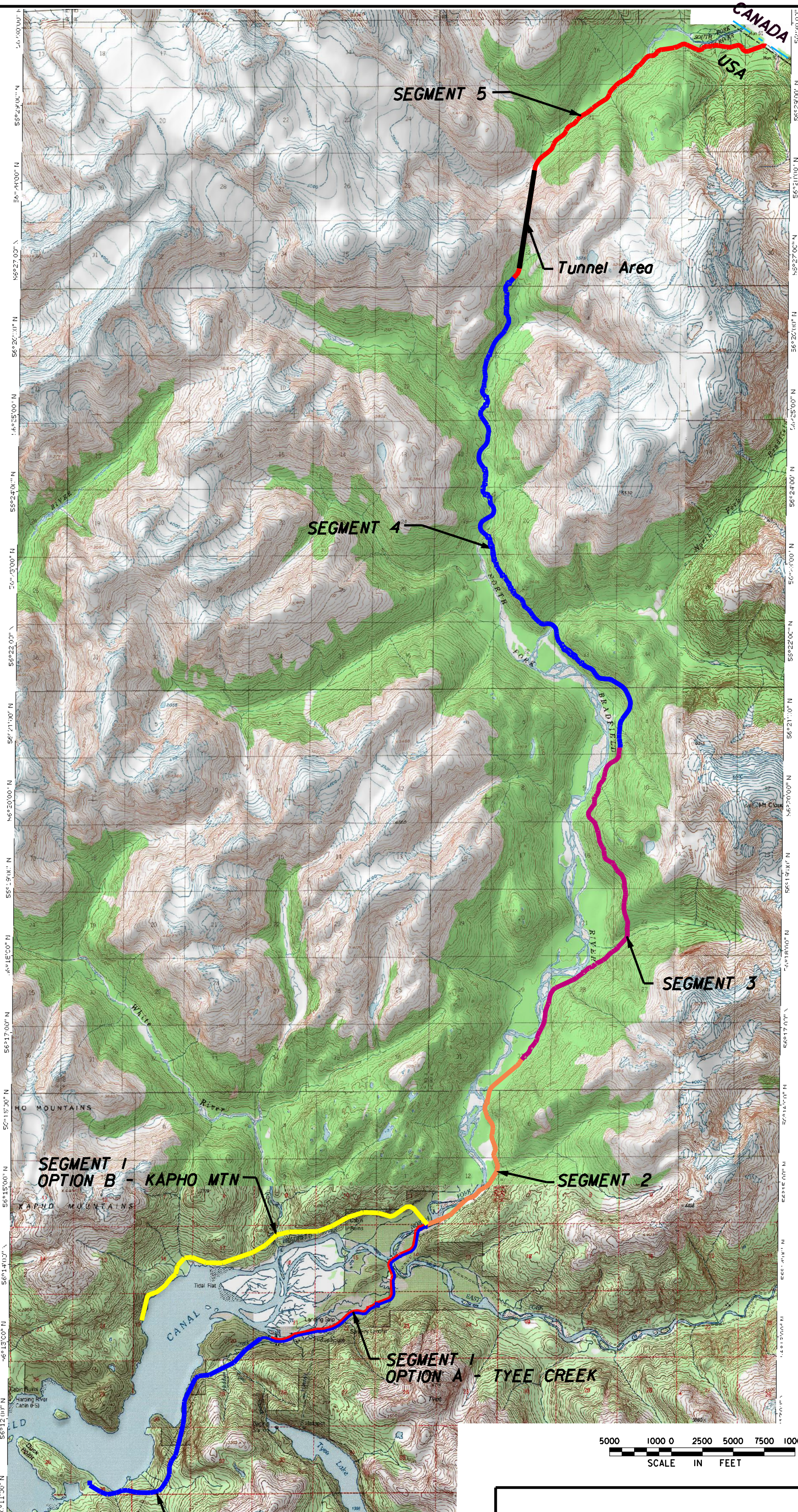


STUDY AREA & CONCEPTUAL ALIGNMENTS

Designed by: AK/WA DESIGN TEAM	Checked by: J. RITTER

Western Federal Lands Highway Division (WFLHD) of the Federal Highway Administration, in cooperation with the Alaska Department of Transportation and Public Facilities (ADOT&PF), the U.S. Forest Service, Alaska Region (USFS), and the City of Wrangell, is the lead agency responsible for completion of this pre-NEPA engineering feasibility study. The purpose of the study is to develop a quantity-based estimate of a land link transportation route from the mouth of the Bradfield River to the Canadian border. This publication is a conceptual analysis that examines various route alternatives within the Bradfield Canal, the Bradfield River drainage and the headwaters of the Craig River drainage. Previous studies that examined access from the city of Wrangell to Canada are summarized in the *Economic Assessment of the Bradfield/Iskut Transportation Corridor,* prepared for the Alaska Department of Community and Economic Development by the McDowell Group. Traffic estimates utilized in this report for design purposes were developed in the *Economic Assessment of the Bradfield/Iskut Transportation Corridor* report.

ADOT&PF, in addition to the activities described above, is the designated funding agency and provided High Priority Project funds to WFLHD to administer. The *Southeast Alaska Transportation Plan (SATP) August 2004* generated by ADOT&PF actively supports an alternative for a road connection from Southeast Alaska to the Cassiar Highway in Canada.

The City of Wrangell, in cooperation with WFLHD, was responsible for coordination with the Canadian representatives, local communities, tribal entities, and local interest groups, and all public involvement processes associated with this project. WFLHD was designated in the Project Agreement to be the lead agency contact in securing needed agreements with the International / Canadian Federal Government. This responsibility was assumed by ADOT&PF. ADOT&PF is working with the Canadian regional governments to develop an International Memorandum of Understanding pursuant to the study of an overland transportation link between the State of Alaska and British Columbia.

The USFS's participation included providing necessary USFS clearances / permits and other pertinent information necessary for completion of the scoping study. In addition to attending agency meetings and participating in public information processes where appropriate, the USFS authorized activities and actions on National Forest lands.

Bradfield River Corridor

The transportation route analyzed in this report is divided into five segments for design purposes. The alignments included in this report begin with three alternative options for segment 1 that originate at locations identified by ADOT&PF as starting points for this quantity based estimate. The total length of this transportation route varies between 27.47 miles, 29.09 miles, and 32.20 miles dependent on the option used for segment 1. See Appendix A for project maps and alignment detail sheets for each option and segment. A major component of this conceptual design is the proposed 8000 linear foot tunnel contained in Segment 5, which connects the

Bradfield River drainage with the Craig River drainage. Appendix E contains the entire tunnel feasibility and cost estimate report.

The conceptual cost estimate developed for this study utilized bid tabulations extracted from a recent WFLHD project that were the most comparable in Southeast Alaska and tunnel costs shown in Appendix E. Table 1, Conceptual Cost Estimate Summary, summarizes construction costs along with Engineering services, EIS costs and Design Engineering and Administration estimates. Conceptual project totals ranged from approximately $241 million up to $352 million (2004 dollars). A breakdown of the Cost Estimate Summary is shown in Appendix B.

It is important to note that ADOT&PF has performed an independent review and redesign of the alignment contained in Option 1A. The design comparison completed by ADOT&PF reflects a preliminary cost estimate of $175,532,200, which is a substantial savings to what is shown above. ADOT&PF also recommends that an alternate route along the north side of the river should be investigated for further cost savings and improved location for a ferry terminal. The analysis and recommendations by ADOT&PF illustrate that many other alignments are feasible, all of which will be fully analyzed during the NEPA process.

Introduction

Bradfield River Road project is a Pre-NEPA Feasibility Study of an over-land link from Southeast Alaska to Canada. The study area begins about 25 miles southeast of the City of Wrangell, Alaska, near the head of the Bradfield Canal. The Bradfield Canal is an 18-mile long fjord leading to the mouth of the Bradfield River. From the mouth of the Bradfield River, the proposed road alignment follows the North Fork of the Bradfield River for 23 miles, where it crosses into the South Fork of the Craig River drainage through a proposed 1.5-mile long tunnel, and thereafter follows the Craig River for 4.5 miles to the Canadian border. Project maps are provided in Appendix A. Total project length within the U.S. is approximately 29 miles. A corresponding 35-mile study of a potential link with the Canadian highway system is being coordinated in Canada by the Alaska Department of Transportation and Public Facilities (ADOT&PF).

The Tyee Hydroelectric Project power-generating facility, located near the mouth of the Bradfield River, is the only development in the study area. Currently, the mouth of the Bradfield River is accessible via boat or floatplane along the Bradfield Canal. A gravel landing strip for small, wheeled aircraft is located near the Tyee Hydroelectric Project. A gravel road heads north for about 2.4 miles, from the hydroelectric project to a washed-out log bridge on the East Fork of the Bradfield River. From this crossing, the abandoned logging road continues several miles along the North Fork of the Bradfield River; however, it is nearly obscured by river erosion and vegetation. The Tyee Hydroelectric facility maintains an existing road from the power facility to the washed-out bridge that can be traveled by vehicle; beyond the bridge, ground access is limited to foot, jet boat, or helicopter travel.

The conceptual design and cost estimates were prepared by the Western Federal Lands Highway Division of the Federal Highway Administration (WFLHD) for the Alaskan portion of the road study, from a deep water access near the head of Bradfield Canal to the British Columbia border. The City of Wrangell, working with the assistance of the municipalities of Petersburg, Craig and Ketchikan, is actively seeking the support of Northwest British Columbia communities and businesses, and the British Columbia provincial government. The U.S. Forest Service is also a cooperating agency on this study. Funds were secured for the conceptual engineering assessment and environmental overview phases from High Priority Project Funds Section 1601.

At this time, WFLHD is focusing its study efforts on a two-lane paved roadway, designed to American Association of State Highway and Transportation Officials (AASHTO) standards for rural collectors. Several other studies have looked at other options that included single lane gravel roads, but WFLHD intends to use the rural collector design standards as a benchmark for comparisons of various alternative alignments and design standards. There are currently three different tidewater termini that are included in the study as potential deep-water ports for the proposed ferry terminal at the head of Bradfield Canal (beginning of the project), and their merits and shortcomings will be discussed in the technical narratives.

Purpose of the Pre-NEPA Engineering Feasibility Study

WFLHD of the Federal Highway Administration (FHWA), in agreement with the City of Wrangell, ADOT&PF, and the U.S. Forest Service, Alaska Region (USFS) conducted a Pre-NEPA Engineering Feasibility Study of a transportation corridor in the vicinity of the Bradfield River and Craig River drainages. WFLHD is the lead agency for this engineering study.

The engineering portion of this study included conceptual investigation for the feasibility and associated costs for an overland road access. The following tasks were included in the engineering study:

- Review information in previous reports
- Collect and provide the following preliminary information
    - Conceptual geotechnical overview
    - Conceptual hydraulic overview
    - Conceptual impact analysis overview
    - Conceptual plans of design alternatives
- Conduct the following analyses:
    - Corridor survey and mapping
    - Analysis of proposed tunnel
    - Cost analysis and estimates
- Coordinate the above activities with all involved government entities

The purpose of the study was to identify and evaluate a feasible alternative for a transportation corridor from the Bradfield Canal up the Bradfield River and Craig River drainages to the U.S./Canada border. All alignments were developed at a conceptual level, based on a reconnaissance level of data collection. The data gathered for these conceptual alignments could be utilized in future design studies of this proposed transportation corridor.

Project Study Area

The study area is located within the Tongass National Forest, approximately 60 miles north of Ketchikan, and 25 miles southeast of Wrangell, where Segment 1 Options A, B, & C begin near the mouth of the Bradfield Canal. The study continues 22 miles up the Bradfield River Valley to the proposed tunnel location, and 4.5 miles down the Craig River drainage to the U.S./Canada border. The legal geographic area within which the study area is located is as follows: Township 65 S Range 89 E; Township 65 S Range 90 E; Township 64 S Range 90E, Township 63 S Range 90 E; Township 62 S Range 90 E, all in the Copper River Meridian. Refer to the regional and vicinity maps provided in Appendix A, Sheet A.3.

Design Assumptions

The design standards shown below were derived from “A Policy on Geometric Design of Highways and Streets 2001”, Fourth Edition, by the AASHTO, and from discussions with representatives of ADOT&PF, the City of Wrangell, and USFS.

- Future Average Daily Traffic (ADT) in the year 2010 will not exceed 400
- Design Speed: 35 miles per hour (MPH)
- Minimum Horizontal Clearance: 10-foot (10’0”) lane, bounded by two 2-foot (2’0”) shoulders
- Maximum Grade: 10%; Desirable Maximum Grade: 8%
- Pavement Design: 4 inches (4”) Asphalt Surfacing; 5 inches (5”) Aggregate Base; 8 inches (8”) Select Borrow
- Superelevation: 6%
- Minimum Horizontal Curvature: 380 feet (380’0”)

The conceptual design values were based on AASHTO highway standards for “collectors” in rural areas. Design assumptions for the roadside environment (outside the shoulder edge) do not incorporate additional widths for curve widening, guardrail, intersections and other miscellaneous widening situations. LIDAR information is not precise enough for these determinations and further engineering will be required for the roadside environment.

The conceptual alignment and all analytical conclusions shown in the plan and profile sheets have been identified through orthophotography and LIDAR mapping analysis. No ground proofing was conducted, and further ground analysis will be required to verify all aspects of these conceptual designs.

Operational Assumptions

The study assumes that the Bradfield River Road will be in operation year round. Potential geological hazards identified along the corridor include debris flows and snow avalanches, which could affect year-round operation and necessitate a future detailed hazard risk assessment for these factors. Therefore, conceptual design alignments and grades incorporated only a general assessment of the area.

Based on the identified hazard potential, a road maintenance facility along the Bradfield River corridor will most likely be necessary. The scoping process also identified the potential need for a staffed U.S. / Canada border station. Both facilities may be required for the future operation of this transportation corridor, but are outside the scope of this study and are not included in this engineering report.

An electrical utility line will be necessary to power the proposed tunnel and other proposed facilities. This study assumed that the line will originate from the Tyee Hydroelectric Project facility at the head of the Bradfield River Valley and will be trenched alongside the alignment of the proposed road. Installation costs on a per-mile basis have been included in the proposed project cost estimate, but no design has been proposed.

Methodology

WFLHD began the engineering process by reviewing previous studies concerning access along the Bradfield River and Craig River drainages as described Section I, pages 10-11. Based on information in these reports, the project termini were developed and a general alignment was plotted on topographic maps of the area.

Based on topographic maps, a project corridor was developed and mapped by acquiring high-resolution LIDAR and color orthophotography of the proposed project area. GEOPAK Digital Terrain Models (TIN files) based on approximate 3-foot intervals were produced from the LIDAR data.

Utilizing the TIN files, conceptual alignments were then developed throughout the proposed corridor. WFLHD formed a Cross Functional Team (CFT) comprised of a Hydrologist, Geotechnical Engineer, Environmental Specialist, Bridge Engineer, and Road Designer, which conducted a preliminary aerial field review of these conceptual alignments. For design purposes, the proposed corridor was divided into five different segments. Each segment included various alignment alternatives that were field-checked by the CFT. The CFT based its recommendations on the feasibility and estimated costs of construction, environmental concerns, and geological hazards, and used these factors to conceptualize one alignment from which a quantity-based estimate could be developed. Conceptual design plans and cost estimates for the proposed alignment were presented to ADOT&PF, USFS, and the City of Wrangell for review. Feedback received from these three agencies expanded the starting termini to include two additional options and was then incorporated into Segment 1: Option A (original scoped terminus), Tyee Hydro; Option B, Duck Point; and Option C, Kapho Mountain. There is one common proposed alignment for the remaining segments (segments 2 through 5).

Previous Bradfield-Related Studies

The Bradfield Canal region has been the subject of numerous transportation studies over the years. The project was originally proposed as providing a land-based link between Southeast Alaska and the continental road system to support mining activity in British Columbia. Proponents of the road have also pointed to the economic benefits of enabling faster movement of seafood and timber products to market, and the potential benefits of a link with the Canadian power grid. The Bradfield route began to receive serious consideration in the mid to late 1980s as a result of mining activity in the Iskut River area. The area saw a surge of mining activity, much of it supported through Wrangell via aircraft or watercraft. Recognizing the potential economic benefits for Alaska from a road link to the Iskut area, in 1990 the Alaska Legislature passed House Bill 311, authorizing the issuance of revenue bonds for up to $22.3 million for construction of a Bradfield River resource road.[1]

Some previous studies examining the feasibility of constructing a road to the Bradfield Canal include:

[1] "Bradfield Road Status Report", Senator Robin Taylor, July 1992.

- *Bradfield Industrial Road Feasibility Study* prepared by S.C. Jacoby and Associates for the Alaska Department of Transportation and Public Facilities, 1989. The study concluded a mine access road could be built from the Bradfield Canal to the Canadian border for $23 million including the construction of a tunnel. The DOTPF concluded that costs were underestimated by $40 million. In 1997, the DOTPF estimated a one-lane gravel road and tunnel would cost $65 million, but concluded the BC government would not support the road on the Canadian side because a port on Bradfield Canal would compete with the existing ports of Stewart and Prince Rupert.

- *A Benefit Cost Analysis of Transportation Alternatives for the Iskut Valley* prepared by Clayton Resources Ltd. for the British Columbia and Canadian governments, 1989. The study forecast that four proposed BC gold mines might benefit from the road. For two of the mines, a $25 million savings was estimated for a road versus air transport. For the other two mines, a $9 million savings was projected from the avoided cost of building a privately financed road and $9 million savings for reduced exploration costs. The Johnny Mountain and Snip gold mines were short lived and used hovercraft and air transport services from Wrangell. The Eskay Creek mine built part of the Iskut road. The Sulphurets property was never developed.

- *A Benefit/Cost Study for the Proposed Ketchikan/Bradfield/Cassiar Transportation Corridor* prepared by the McDowell Group, Inc. with Peratrovich, Nottingham, & Drage, Inc., Avalon Development Corporation, and BST Associates for the Alaska Department of Commerce and Economic Development, 1994. The study found a benefit cost ratio of 1.24 for a Bradfield pioneer road, and 0.76 for the two-lane highway.

- The US Department of Agriculture and Forest Service in 1998 estimated the cost of a public highway from Ketchikan to the border at $340 million. The Forest Service also estimated the cost of the Canadian portion at $87 million. In March 2003, The USDA Forest Service reviewed a wide range of Southeast Alaska proposed public road and ferry projects. Their estimate for 14 miles of new road and 14 miles of upgrading an existing forest service road from Bradfield to the border was $140 million.

- The *Southeast Alaska Transportation Plan* includes the Bradfield road and various related developments. The plan places traffic on the Bradfield at 100 AADT in 2011 increasing to 130 AADT by 2021, with summer ADT at between 270 and 320 for the same period. The cost of the project is estimated at $257 million for the 28 miles to the border, $58 million for the Fools Inlet Road and ferry terminal, and $16 million for the Fools Inlet ferry (to Bradfield). The study also estimated the cost of the road from Ketchikan to Bradfield at $258 million.

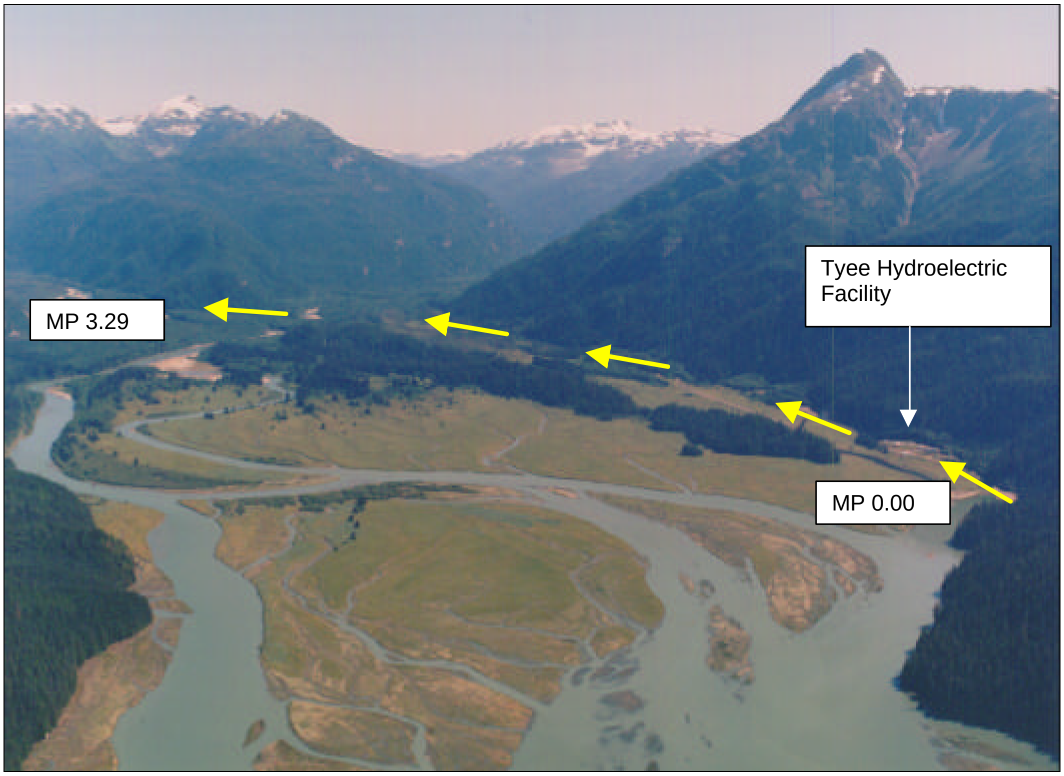
These previous studies provide important guidance in the development of the scope and workplan for the *Economic Assessment of the Bradfield/Iskut Transportation Corridor*. This more comprehensive and updated analysis is essential because of changing economic and political conditions on both sides of the Alaska / BC border.

Segment 1 Option A, Tyee Hydro

This segment begins at the west end of the existing road serving the Tyee Hydroelectric Project facility, where Tyee Creek flows into the Bradfield River. The existing road, currently under the ownership of the State of Alaska is approximately 2.5 miles in length. The road sustains minimal traffic, and appears well maintained. The conceptual alignment follows the existing road through the hydroelectric plant's housing facilities. Prior to reaching the hydroelectric penstock at milepost (MP) 0.36, the conceptual alignment was shifted westerly 200 feet, and parallels the existing road for approximately 2,500 feet. This will allow hydroelectric personnel to access and maintain the penstock facility. Access to the Tyee penstock will need to be evaluated further, and included in the design and cost estimate. At MP 0.61, the alignment crosses the discharge of the penstock and will require either a bridge structure or large culvert, for the purposes of this conceptual study we estimated costs for a bridge structure. The realignment rejoins the existing road at MP 0.80, just prior to the intersection with the Tyee aircraft landing strip. This intersection should also be included in any future final design and cost estimates for the project. The conceptual alignment continues to follow the existing road alignment to MP 2.30. Beyond this point the existing road continues easterly for approximately 1000 feet to a collapsed log stringer bridge. The log abutments are still intact, but aerial observation of this old crossing shows the location to be in the channel migration zone. For this reason, at MP 2.30 the conceptual alignment leaves the existing road and continues northward to MP 2.60, where bedrock is present on both sides of the river and the channel is more confined. At this location (MP 2.60), a crossing was identified that will require an estimated 325-foot bridge structure. All river crossings have been identified through orthophotography and LIDAR mapping, and will require further analysis to verify this as an acceptable bridge location. From MP 2.6, the conceptual alignment then moves eastward to the base of a solid rock bluff, and follows the old logging road alignment at the base of the bluff to the terminus of this segment at MP 3.29.

(See photo next page)

Figure 1. Segment 1, Option A, Tyee Hydro



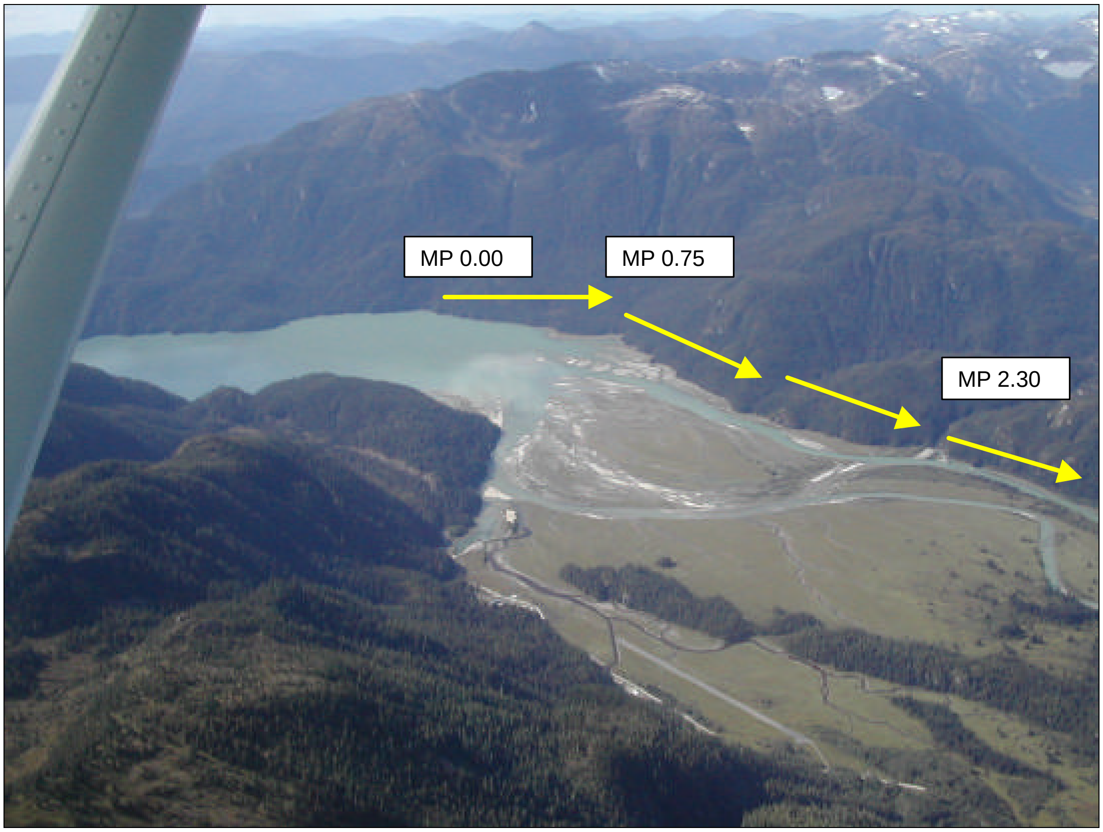
Construction of this segment is anticipated to be moderately difficult. The large, flat flood plains provide for construction staging areas and potential opportunities to utilize excess excavation from the adjacent road segments. This alignment crosses muskeg areas. These crossings will require additional investigation to determine muskeg depth and appropriate stabilization methods.

The CFT designed and evaluated an alignment at MP 3.29 that crossed over to the north side of the North Fork of the Bradfield. However, for this conceptual study, due to the vertical rock slopes on that side of the river and the need for an extensive bridge span, the CFT decided to concentrate design efforts on the southeast side of the North Fork.

Segment 1 Option B, Kapho Mountain

This conceptual alignment begins at a potential location that may provide deep-water access to the north side of the mouth of the Bradfield Canal. It is also the most westerly point that contains current LIDAR data and where a geometric design can begin. For approximately 3.4 miles the alignment is adjacent to the Bradfield River and is generally positioned on steep, rocky side slopes that will require full bench blasting and retaining walls to contain the full roadway width. At MP 0.75 the alignment crosses a confluence of three stream drainages, and will require an estimated two bridge structures approximately 100' each in length. The alignment continues along the base of the rock cliffs, above the river channel to MP 2.30, where it crosses a large drainage and will require an estimated 225-foot bridge span. The same terrain features continue along the alignment approximately up to MP 3.50. At this point the Bradfield River bends to the southeast as the conceptual road alignment continues toward the northeast, along the base of the mountainside, but includes the additional area to utilize the excess excavation in the conceptual road design. At MP 4.55, the alignment crosses approximately 0.30 miles of muskeg flood plains to milepost 4.85, where the North Fork of the Bradfield River could be crossed. The river crossing is estimated to require a 400-foot bridge to reach the alignment terminus at MP 4.94.

Figure 2. Segment 1, Option B, Kapho Mountain

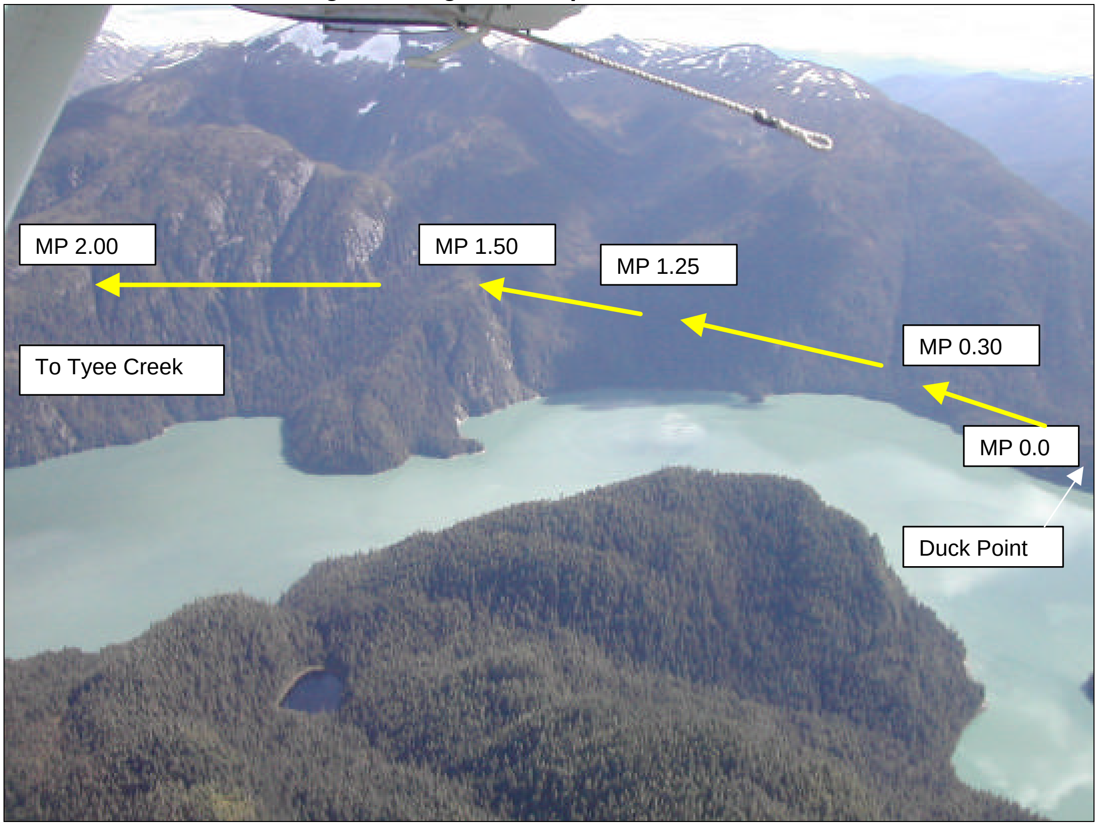


Construction of this segment is anticipated to be very lengthy and difficult. The large, full bench cuts into solid rock will pose considerable challenges for containing the excavation materials during blasting, as well as construction of the long bridge spans. In addition, the first 3.5 miles contain limited opportunities to use the excess excavation, and may require long hauls to place excess excavation and unsuitable materials. The portion of the road between mileposts 3.54 and 4.94 does provide an opportunity to utilize the excess excavation in the roadway, and is adjacent to flat muskeg areas that could be utilized as construction staging areas.

Segment 1 Option C, Duck Point

The alignment from Duck Point to the Tyee Hydroelectric Project facility was located outside the initial scope of this study and was not included in the LIDAR and orthophotography of the project. The conceptual alignment and profile shown on this option is conceptualized from U.S. Geological Survey (USGS) topography maps of the area. All quantities reflected in the cost estimate are estimated on a route-mile cost basis, not on geometric design quantity-based numbers.

Figure 3. Segment 1, Option C, Duck Point



The vertical solid rock cliff face in this area will require extensive analysis to determine if an overland route through this area is possible. Major drainages located at approximately MP 0.30 and MP 1.25 will require significant bridge structures and require further analysis to determine the appropriate length and type of structure. From approximately MP 1.50 to 2.00 there are several deeply incised avalanche chutes cut into the vertical rock cliff face, an alignment crossing horizontally along these chutes would require extensive geotechnical and engineering analysis to determine if an alignment is even feasible. Topography maps indicate the rock cliffs rise to an elevation of approximately 2500' and there does not appear to be an alternative route over the top of mountain.

Assuming an overland route is possible, the large, full bench cuts in solid rock anticipated along the cliff faces will pose considerable challenges to drilling and blasting. Containment of the excavation materials during blasting will also pose significant problems. Long hauls to place excess excavation can be anticipated because the conceptual alignment contains limited opportunities to utilize the materials. Road construction around the solid sheer rock cliffs along the alignment may utilize features such as elevated causeways and retaining walls to limit the high excavation costs.

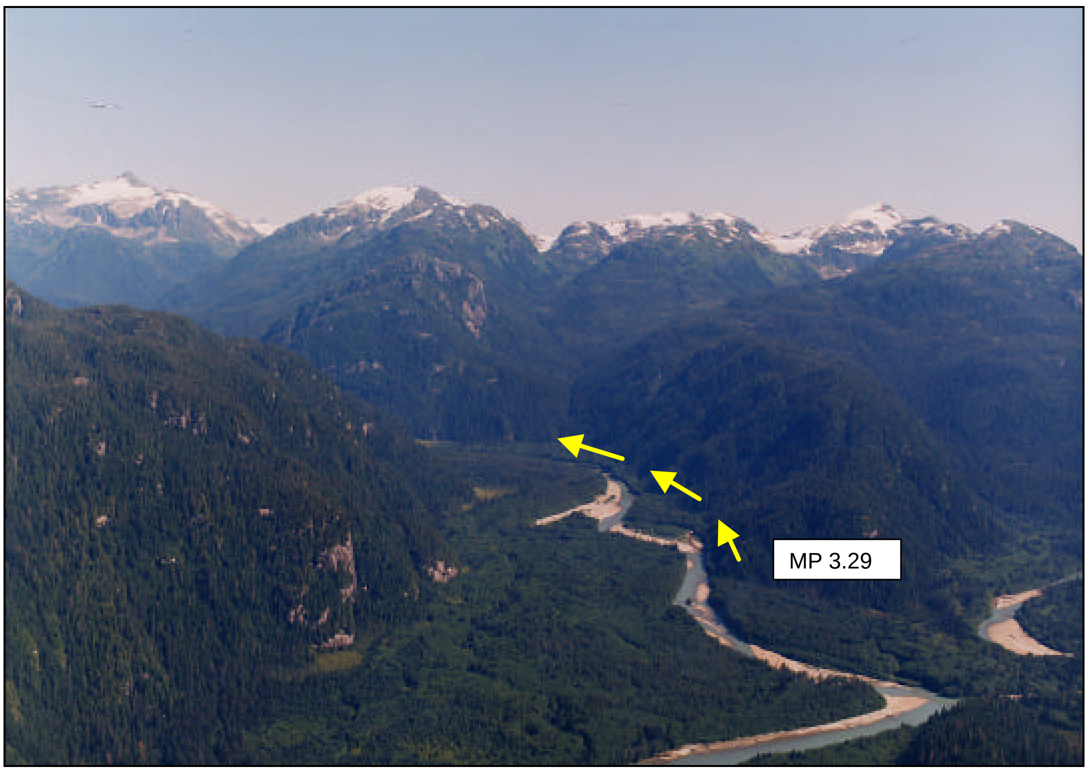
Safety considerations, environmental impacts, and the high cost of an overland route suggest that a tunnel should be studied as an alternative to standard road construction.

Segment 2

This conceptual road alignment begins at the same intersection point as the ending stations from Segment 1 Option A, Option B, and Option C: MP 3.29. This milepost is located just past the confluence of the East and North Forks of the Bradfield River, and marks the end of the tidal influence. Remnants of an abandoned logging road can be seen throughout this segment and in the ensuing segments up to MP 16.00.

This conceptual alignment begins along the base of a steep rocky mountain slope with large cuts and retaining walls on the fill side. At milepost 3.70, the river meanders to the west side of the valley floor and the alignment stays to the east along the base of the mountainside, allowing large fills to be designed in, up to MP 5.75. From milepost 5.75 to 6.00, the river flows against a large rock outcropping, requiring deep cuts and retaining walls. From MP 6.00 to the end of the segment at MP 6.78, the valley floor opens up again, and the road prism can be constructed utilizing fill material.

Figure 4. Segment 2



Revetment walls were proposed at locations to offset the erosion potential of the river while retaining walls were designed to limit the embankment from encroaching into the river. Revetment wall and retaining wall locations were based on cross sections of the alignment and a rough analysis of the stream flow. The conceptual alignment is designed to stay at the base of the surrounding forested mountain slopes, while maintaining a minimum elevation of at least 15 feet above the channel bottom. The now abandoned 14 miles of logging road was laid out in the late 1970's and utilized river borrow as a material source. It has since been washed out in many locations by the changing river channel. The meandering river channel is in a constant state of flux due to the introduction of sediment from the glacial melt and surrounding mountain drainages.

The two areas with large cuts will present some construction issues but construction is expected to be moderately difficult. There are opportunities along this segment to utilize the excess excavation in the road embankment, thereby limiting haul costs.

Segment 3

This segment of alignment begins at MP 6.78, where the river valley has widened out and the river channel has meandered to the west side of the valley. The road alignment continues up the east side of the valley, and is positioned against the toe of the mountain slope. At approximately MP 7.10, the valley narrows and the alignment remains east of the river while maintaining a grade 15 feet above the channel bottom. As the river channel meanders and bends, the conceptual road alignment has been designed to include more revetment walls. Further analysis will be required to determine the appropriate size for the riprap in the revetment walls to ensure embankment stability.

At approximately MP 9.05, the alignment crosses on the west side of a confluence of two streams, which is anticipated to require a 200-foot bridge. The location of this crossing will require further investigation to ensure the bridge is placed in a stable location. At approximately MP 9.50, the river again meanders to the west side of the valley floor, while the road continues along the toe of the east slope. Although the alignment in this area is a considerable distance from the river channel, several overflow channels meander up against the toe of the east slope. Because the river channel is in constant migration, it is necessary to maintain a minimum 15-foot elevation above the channel bottom. Maintaining this grade in steep side slopes requires designing additional Mechanically Stabilized Earth (MSE) walls to contain the fill and prevent encroachment into the overflow channels. From approximately MP 11.10 to MP 11.30, the river channel turns abruptly into the east slope, where steep rock outcrops are located. This situation creates a combination of large cuts in the rock and retaining walls to contain the road embankment. This is an area that will require special consideration and engineering to ensure the road alignment is properly located. From MP 11.30 to the segment terminus at MP 12.33, the alignment continues along the east side of the valley, away from the river channel.

Figure 5. Segment 3

The abandoned logging road is still visible in many areas, meandering thru the floodplain. This segment of proposed new alignment is conceptualized in a more stable location, and is anticipated to require approximately 1.4 million cubic yards of excavation. Further evaluation and engineering should reveal opportunities to reduce the excavation quantities, but the steep side slopes along this segment will keep the costs of road construction high.

Segment 4

Segment 4 of this proposed design alignment begins at MP 12.33, and continues along the east side of the valley floor, while the current river channel is located up against the west side of the valley. At approximately MP 12.75, the alignment crosses a drainage that will require a bridge structure of approximately 200 feet. As noted previously, the bridge lengths are rough estimates generated from the LIDAR survey and orthophotography, and any change in the conceptual alignment will affect the lengths and types of bridge structures. At approximately MP 13.65, the river meanders back up against the easterly slope where the alignment is located, and limits the placement of embankment slopes, thru cuts and retaining walls that are necessary to reduce the footprint of the roadway.

At approximately MP 14.00, the main confluence of the North Fork of the Bradfield River meets another drainage that is also mapped as the North Fork of the Bradfield

River. The alignment continues along the northeastern slopes of the valley, crossing the easterly drainage mapped as the North Fork of the Bradfield River at MP 14.75. This drainage crossing has a narrow steep channel that abruptly fans out into the Bradfield River Valley. The conceptual design anticipates a curved bridge structure approximately 500 feet in length. From MP 16.00 to MP 16.50, the river channel is again located up against the easterly slopes of the valley floor, thereby restricting the placement of embankment slopes. As the river abruptly turns toward the northeast, the channel becomes more restricted and provides opportunity to cross over to the west side of the Bradfield River Valley at approximately MP 16.70, which will require an approximately 350-foot bridge. The slopes of the west side of the valley are also steep and require the use of retaining walls and thru cuts to prevent the footprint of the roadway from encroaching into the river.

One important factor is that at approximately MP 17.40 a sizeable tributary on the east side of the valley continues to release a considerable amount of sediment and boulders. It appears the mass events that created the alluvial fan at the valley floor may have been fairly recent, and this factor directly affected the decision to cross to the west side of the North Fork prior to reaching this location.

At MP 18.96, a 300-foot bridge crossing is necessary, while an additional 170-foot bridge crossing is required at MP 19.30. An alternative alignment that would pass northwest of MP 18.96 and require only one bridge crossing was analyzed, but the slopes in the confined channel were too steep to place a geometric alignment. Upriver of MP 19.30, the alignment continues in a northerly direction and stays on the west side of the valley up to the southern tunnel portal. At MP 20.50, prior to the tunnel portal, the river channel makes an abrupt turn to the east. The drainage area in which the southern portal is located, is broken by ridges and many glacial fed tributaries that will require fairly large culverts along the alignment. The steep grade leading up to the portal was designed at 9.3 percent to limit the amount of excavation; future analysis may be able to further reduce the grade. The terminus of this segment of conceptual road alignment is MP 21.06.

Figure 6. Segment 4, MP 16.20 to MP 19.30

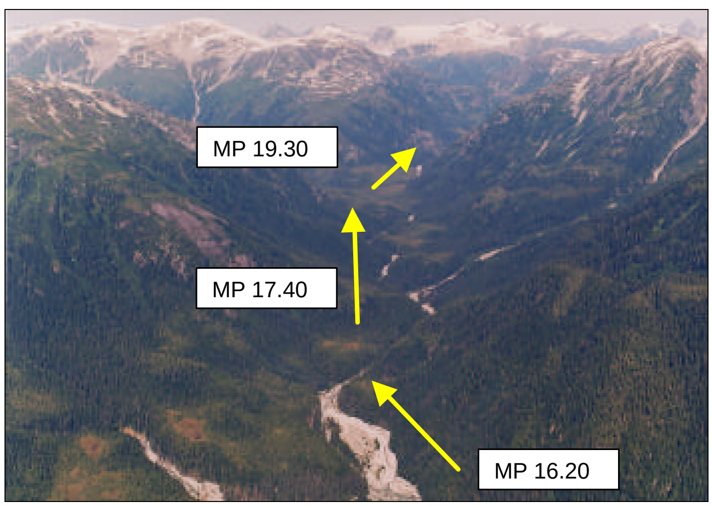
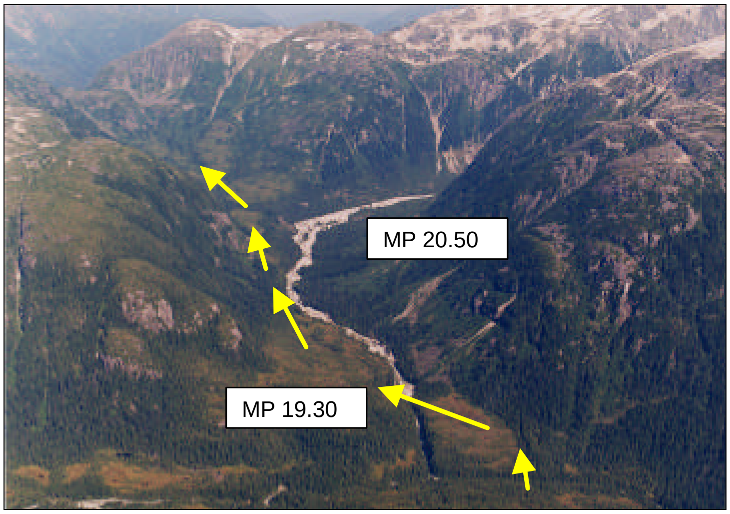


Figure 7. Segment 4, MP 19.30 to MP 20.50

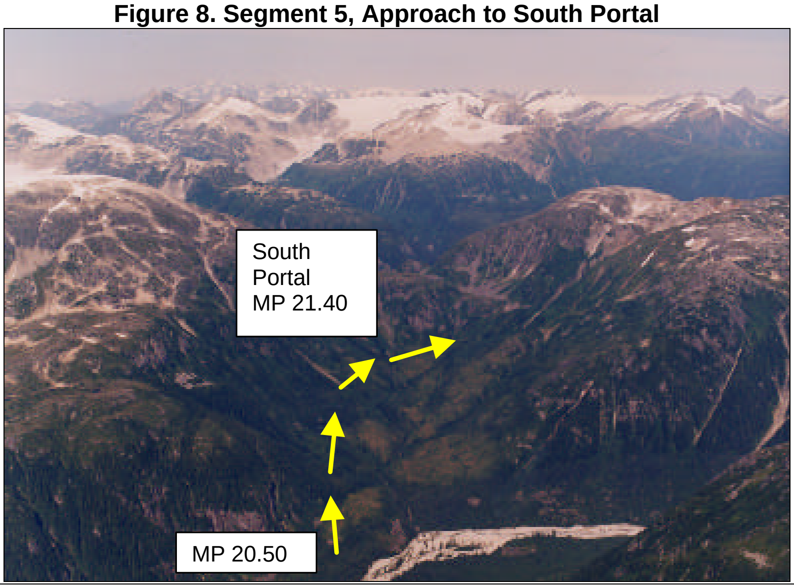


This segment of conceptual alignment contains many challenges for the construction of a transportation corridor. Due to the steep valley slopes, hard granitic rock, and five locations that require bridges, the excavation process will be costly and time consuming. More refined engineering may be able to reduce the excavation quantities but there are limited areas where excess excavation can be used, and some long hauls may be necessary.

Segment 5

From approximately MP 21.06 to MP 21.20, the alignment is located at the confluence of two sizeable drainages that will require large culverts with deep fills to construct the steep 8.3 percent grade up to the proposed southern tunnel portal. Refer to Appendix E for an analysis of the tunnel alignment.

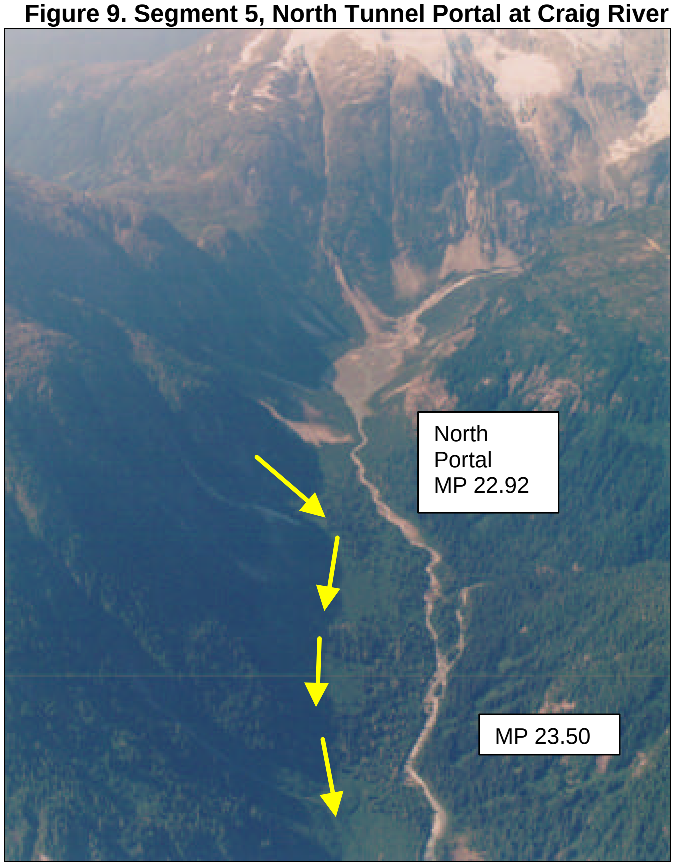
Figure 8. Segment 5, Approach to South Portal



The alignment exiting the northern portal traverses a -5.6 percent grade on large fills. Excavation materials from the tunnel could be utilized in constructing the proposed grade. As the alignment exits the portal, the location was balanced between the head of the Craig River to the west, and the avalanche chutes that come off of the glaciers above the east side of the Craig River Valley. Critical areas at approximately MP 23.75 and MP 24.15 will require further engineering to determine exact alignment.

At approximately MP 24.50, a stream crossing will require an anticipated 185-foot bridge structure. The alignment continues in a northeasterly direction at the toe of the Craig River Valley. At MP 25.20, an overflow channel from the Craig River meanders up against the alignment along the eastern slopes for about 1,000 feet, which requires the alignment to be designed into the mountain slope, and necessitates sizeable thru cuts. The valley floor then opens up, and the river channel veers to the northeast while the alignment follows the toe of the mountain slopes in an easterly direction. At MP 26.05, the river channel again meanders back toward the toe of the slopes, but there is ample room to construct the road alignment utilizing fill material. The alignment continues to approximately MP 26.60, where a drainage will necessitate a 350-foot bridge structure crossing. The drainage is located on the toe of an alluvial fan, and further analysis will be required to ensure that this is the proper crossing location. The road alignment continues in a northeasterly direction to the U.S./Canada border, to the terminus of this segment at MP 27.44.

Figure 9. Segment 5, North Tunnel Portal at Craig River



This segment of road alignment poses several construction challenges as it traverses several alluvial fan areas that will require additional exploration. However, overall the majority of the conceptualized alignment grade utilizes the anticipated excess excavation materials from the tunnel construction. The adjacent slopes appear to provide opportunities to place large amounts of fill material, on which the road can be located. The area of greatest concern is the segment leading up to the southern portal, where construction of large fills and large culverts will be time consuming and costly.

Cost Estimate Summary

The cost summary sheet was based on bid tabulations extracted from WFLHD project AK PFH 44-1(1), Coffman Cove Schedule B. Bid tabulations on the Coffman Cove Project were received in fiscal year 2003. All bid items and unit costs were reviewed by WFLHD field personnel to ensure unit costs were appropriate and applicable. WFLHD CFT also reviewed bid items and unit costs; their input was also taken into consideration in developing the final unit costs reflected in the Conceptual Cost Estimate Summary (see Table 1). Item descriptions, conceptual quantities developed, unit costs and cost estimate background information is shown in Appendix B.

Table 1. Pre-NEPA Conceptual Cost Estimate Summary

Work Item Description	Tyee Creek Option	Kapho Mtn. Option	Duck Point Option					PROJECT TOTALS with OPTIONS		
	SEGMENT NUMBER							SEGMENTS 1A with 2 thru 5	SEGMENTS 1B with 2 thru 5	SEGMENTS 1C with 2 thru 5
	Segment 1			Segment 2	Segment 3	Segment 4	Segment 5			
	Option A	Option B	Option C	2	3	4	5			
LENGTH (Mile)	3.29	4.94	8.02	3.49	5.55	8.73	6.41	27.47	29.12	32.20
DIVISION 1 MOBILIZATION	$692,677	$1,724,615	$6,514,614	$785,008	$1,703,805	$2,581,850	$1,864,121	$7,627,460	$8,659,399	$13,449,397
DIVISION 2 EARTHWORK	$1,075,322	$5,781,332	$53,629,904	$2,166,216	$12,353,989	$8,967,575	$4,878,201	$29,441,303	$34,147,312	$81,995,884
DIVISION 3 UTILITIES & RELOCATIONS	$464,500	$547,000	$701,000	$474,723	$577,277	$736,316	$620,335	$2,873,151	$2,955,651	$3,109,651
DIVISION 4 BASES & PAVEMENT	$786,020	$1,063,780	$1,820,540	$794,220	$1,254,920	$1,944,620	$1,386,940	$6,166,720	$6,444,480	$7,201,240
DIVISION 5 TUNNEL	$0	$0	$0	$0	$0	$0	$75,030,000	$75,030,000	$75,030,000	$75,030,000
DIVISION 6 STRUCTURES	$4,031,500	$10,201,000	$17,162,800	$3,946,000	$3,217,000	$15,735,000	$3,926,000	$30,855,500	$37,025,000	$43,986,800
DIVISION 7 INCIDENTAL CONSTRUCTION	$1,997,725	$2,130,775	$2,383,630	$2,014,931	$2,186,138	$2,190,723	$1,877,676	$10,267,194	$10,400,244	$10,653,099
DIVISION 8 ROADWAY FINISHES	$113,700	$939,000	$283,106	$149,834	$676,366	$996,790	$447,201	$2,383,890	$3,209,190	$2,553,296
SUBTOTAL ROADWAY AND BRIDGE WORK	**$9,161,444**	**$22,387,502**	**$82,495,593**	**$10,330,932**	**$21,969,496**	**$33,152,873**	**$90,030,473**	**$164,645,218**	**$177,871,275**	**$237,979,367**
CONTINGENCIES: 25%	$2,290,361	$5,596,875	$20,623,898	$2,582,733	$5,492,374	$8,288,218	$22,507,618	$41,161,304	$44,467,819	$59,494,842
TOTAL CONSTRUCTION COST	**$11,451,806**	**$27,984,377**	**$103,119,492**	**$12,913,664**	**$27,461,870**	**$41,441,091**	**$112,538,092**	**$205,806,522**	**$222,339,094**	**$297,474,209**
CONSTRUCTION ENGINEERING SERVICES: 8%	$916,144	$2,238,750	$8,249,559	$1,033,093	$2,196,950	$3,315,287	$9,003,047	$16,464,522	$17,787,128	$23,797,937
EIS W/ SUPPORTING ENGINEERING: 5%	$572,590	$1,399,219	$5,155,975	$645,683	$1,373,093	$2,072,055	$1,687,830	$6,351,251	$7,177,880	$10,934,635
DESIGN ENGINEERING & ADMINISTRATION: 8%	$916,144	$2,238,750	$8,249,559	$1,033,093	$2,196,950	$3,315,287	$4,501,247	$11,962,722	$13,285,328	$19,296,137
TOTAL CONSTRUCTION & ENGINEERING	**$13,856,685**	**$33,861,097**	**$124,774,585**	**$15,625,534**	**$33,228,862**	**$50,143,720**	**$127,730,216**	**$240,585,017**	**$260,589,429**	**$351,502,917**
Construction Cost $/Mile	$3,480,792	$5,664,854	$12,857,792	$3,695,476	$4,948,085	$4,748,978	$17,565,691	$7,492,737	$7,635,935	$9,239,055

NOTES:

Segment 5 - EIS and Design Engineering Costs have been proportionately reduced to reflect the lower costs associated with the tunnel. The following formulas have been applied.

EIS - 5% ($112,538,092 Const.Cost - [$75,030,000 Tunnel Cost x 1.25 Contingency Factor]) + (1% x $75,030,000 Tunnel Cost) = $1,687,830

Design - 8% ($112,538,092 Const.Cost - [$75,030,000 Tunnel Cost x 1.25 Contingency Factor]) + (4% x $75,030,000 Tunnel Cost) = $4,501,247

The following bridge crossings have been identified through orthophotography and LIDAR mapping, and will require further analysis to verify the bridge locations and their lengths.

Table 2. Bridge Location Summary

Segment	Beginning Station[1]	Ending Station	Bridge Length (linear feet)	Bridge Area[2] (square feet)	Complexity[3] Low	Medium	High
1 Option A	120+20	121+80	160	4,800		X	
1 Option A	224+74	228+00	326	9,780			X
1 Option B	48+70	49+70	100	3,000	X		
1 Option B	54+00	55+00	100	3,000	X		
1 Option B	132+50	134+75	225	6,750		X	
1 Option B	267+00	270+35	335	10,050			X
1 Option C[4]	48+70	49+70	100	3,000	X		
1 Option C[4]	54+00	55+00	100	3,000	X		
1 Option C[4]	266+35	270+35	400	12,000			X
2	344+15	345+80	165	4,950		X	
3	564+00	566+00	200	6,000		X	
4	761+95	763+35	140	4,200	X		
4	867+00	872+00	500	15,000			X
4	970+50	974+00	350	10,500		X	
4	1089+00	1092+00	300	9,000		X	
4	1107+50	1109+20	170	5,100		X	
5	1381+40	1383+25	185	5,550		X	
5	1494+00	1497+50	350	10,500		X	

[1] Stations shown in Table 2 correspond with the design plans in Appendix A.

[2] Deck area is based on average bridge width of 30 feet multiplied by the estimated length.

[3] Complexity is to denote conceptual range of estimated costs that are shown in Appendix A.

[4] Segment 1 Option C was not included in the original scope of the project and the data included in the engineering study is not based on a geometric design. The data included for Segment 1 Option C is based on a conceptual alignment drawn on a topographic map.

Bridge Assumptions

Unit cost for bridge construction - Bridge construction costs at the scoping stage of a project are typically estimated by applying a "per square foot" cost to the total bridge deck area. These costs are based on historic costs of construction and should be adjusted to account for unique features for the project or structure being considered. The average unit cost for bridge construction in Alaska over the ten-year period from 1993 through 2002 is $127/square foot. This figure compares favorably to the average unit price for bridge construction on WFLHD projects ($131/square foot), including projects in a five state region consisting of Alaska, Washington, Oregon, Idaho, and Montana.

Remote location factors - The limited access to the site is the most significant factor affecting costs. As a consequence of location, builders will have additional costs and difficulty getting equipment and materials to the project. For example, critical equipment such as cranes, which are typically only needed for a short time on the project, will have to be brought in repeatedly on an as-needed basis, or mobilized at the start of construction and left on site for a long duration. On less remote construction sites, this equipment is only brought in when it is needed and then sent back after its work is completed, thus minimizing idle time. The cost of repeated mobilization or the cost of long periods of idle time for this equipment would have to be absorbed in the price of construction.

Similarly, all materials for bridge construction will have to be brought in from somewhere else. Unlike road construction, which can make use of on-site material for building embankment and some portion of the pavement structure, all of the materials for the bridges will have to be brought to the site. This includes concrete, reinforcing steel, pre-cast girders, and even timber used to construct forms. Given the total number of bridges to be built, and the remote site, it is likely that a contractor will set up a batch plant to mix concrete. Again, this is a significant cost including purchase, transport, set-up, calibration, and maintenance. Also, the aggregate and cement will have to be brought in from somewhere else. All of these costs add to the unit cost of bridge construction.

Related to these costs are risks that the builder must consider in putting together a bid. Unlike projects build in less remote locations, there is no margin for error in shipping tools, equipment and material to this site. It will not be possible to send a driver back to town to pick up another load of plywood if needed, for example. Emergency shipments or delays in construction add significantly to cost. Most contractors will cover this risk by raising their unit prices to account for the inevitable surprises that occur during construction.

WFLHD has extensive experience in constructing bridges in remote locations. Costs for these projects often run 25-50% higher than bridges built closer to town.

Complexity - We have attempted to create some degree of calibration in the estimate by distinguishing between three levels of complexity. Generally, the level of complexity is driven by the estimated length of bridge. Additionally, we have considered whether the bridge will include in-stream construction, high substructures, or difficult geometry.

Short bridges (under 150 feet long) will generally be possible to construct as single span bridges. In many cases, these will be made with decked bulb-T superstructures, minimizing the amount of on-site concrete construction. These bridges also have the advantage of relatively quick construction. These crossings are categorized as low complexity. We have used a unit cost of $150/square foot for low complexity bridges.

Medium complexity bridges include those that are too long to reasonably construct as single span bridges. These will require more time, materials, and skill to construct the intermediate piers. They will also require cast-in-place concrete decks, rather than using deck bulb-T girders. (Note: it is sometimes practical to construct longer span bridges, up to 200 feet, as single spans. These are beyond the practical span length for deck bulb-T girders, and thus will require cast-in-place concrete decks.) We have used a unit cost of $200 / square foot for medium complexity bridges.

The third class of complexity includes those bridges that appear to involve in-stream work. This is always going to be the most difficult and consequently, most expensive construction. The builder has to construct stream diversion or cofferdams. Access to the intermediate piers and to the far bank will likely require construction of temporary work bridges across the stream. For the short span crossings, this can be a simple structure. For the high complexity bridges, we anticipate that the temporary work bridges will be a significant effort for the builder to construct. We have used a unit cost of $275 / square foot for high complexity bridges.

Bridge size approximation - It should be noted that the topographic data available at this time is limited to aerial survey. Subsurface conditions at the various crossings have not been investigated. Thus, bridge length at this stage is a conceptual length.

Typically, we set bridge length by identifying the edge of stream (generally at the contour break point at the edges of the stream bed), and project up to the finish profile grade at a slope of 1:1.75. This slope, slightly flatter than the natural angle of repose of riprap, provides a stable embankment and prevents loss of roadway embankment at the ends of the bridge.

On several of these crossings we have made some assumptions that using vertical substructure at the abutments can reduce the bridge length. This includes concrete retaining walls, and, where appropriate, MSE walls located on stable ground well above the active stream channel. Our experience has shown that while this technique reduces the length of the bridge superstructure, thus reducing the deck area, there is a false economy in this approach. The vertical abutment structures end up being higher than the surrounding terrain, and require extended wing walls or retaining walls along the edges of the road to contain the embankment until it is back from the edge of the stream channel. Generally, we have found that the cost of the additional substructure at the abutments roughly equals the cost of bridge length saved.

The conceptual design assumes that the foundation of each abutment would be engineered to withstand natural and load-related forces. Construction of engineered abutments is more expensive than the simpler placement of bridge footings, but prepares the bridge for a long service life and is the best way to ensure that it will remain open to traffic even when subjected to extreme events such as floods.

The Bradfield River Road project area is mountainous, with elevations from 0 to 6000 feet (WGS84). The lower elevations are heavily timbered. Large steep-walled glacial valleys (1000 to 3000 feet wide), dynamic river systems, and active alluvial fans dominate the morphology. Glaciers occupy most of the headwater valleys.

Portions of road segment 1 Option A, Option B, and Option C[2] are in marine and tidal-dominated delta plain areas. Segment 1 Option A and Option C, segment 2, and the lower half of road segment 3 parallel an unconfined and meandering river system (see Figure 10 and Appendix C Figures 2 and 3). The upper half of road segment 3, lower half of segment 4, and most of segment 5 parallel unconfined and braided river systems (see Figure 11 and Appendix C Figures 3, 4, 5, and 6). The upper half of road segment 4 parallels a braided river system that is structurally constricted by steep bedrock valley walls (see Appendix C Figures 4 and 5).

Figure 10. Typical glacial valley and unconfined, meandering stream morphology

(See photo next page)

[2] Data for Segment 1 Option C is based on a conceptual alignment drawn on a topographic map; data is not based on a geometric design.

Figure 11. Typical glacial valley and unconfined, braided stream morphology

Based on the conceptual road alignment and field reconnaissance, road construction will involve:

- Tidal area encroachment
- Floodway encroachment
- Channel migration zone encroachment
- Alluvial fan encroachment
- Bridge installation
- Large diameter culvert installation
- Aquatic organism passage culvert installation
- Minor drainage installation

Tidal Area Encroachment

Based on LIDAR aerial photography, USGS topographic mapping, and conceptual road alignment plans, portions of road segments 1 Option A, Option B, and Option C are in marine and tidal delta plain areas (see Appendix C Figures 1 and 2). Possible impacts to the proposed road include tidal inundation and wave-induced erosion.

No National Oceanic and Atmospheric Administration (NOAA) tidal stations are located near the project. The difference between mean high water (MHW) and mean lower low water (MLLW) for tidal stations at Wrangell, Alaska, and Stikine Straight, Alaska, is approximately 8 feet. Review of United States Geological Survey (USGS) topographic mapping and available NOAA regional hindcast data suggests the proposed road is not likely exposed to strong prevailing winds and long fetches that produce intense erosive wave activity. Based on observed field evidence and extrapolation of the available tidal station records, road areas within 15 feet above the MLLW may be subjected to inundation and moderately erosive wave activity.

Set the road profile at least 20 feet above the MLLW. Protect road areas where the embankment is within 15 feet above the MLLW with riprap revetments. Estimated revetment locations are presented in Appendix C Table C-1. Stabilize natural areas that are experiencing erosion and near the proposed road corridor with riprap revetments. Locate retaining wall foundations within the marine and tidal delta plain areas on bedrock. Retaining walls constructed of stone-filled wire-mesh baskets will be subjected to aggressive corrosion in the marine environment. Limit wire-mesh basket use to areas above the MHW and away from ocean spray.

Floodway Encroachment

The river floodway conveys all of the normal stream discharges and most of the flood discharges. An active channel defines it. LIDAR aerial photography, USGS topographic mapping, and conceptual road alignment plans were used to delineate areas that appear to encroach into the river floodway. The revetment symbols in Appendix C Figures 2, 3, and 4 identify anticipated encroachment areas. They are typically located at constriction points, meander bend apexes, and where the river channel has truncated against valley walls.

Figure 12. Floodway encroachment at Segment 2, typical for project

Road embankments that encroach into the floodway will experience erosive shear stresses and frequent flood inundation. Evaluate cost-effect alternatives to floodway encroachments during roadway design. Protect encroachments that cannot be cost-effectively avoided with riprap revetments.

To develop the conceptual level design and cost estimates, set the road profile at least 15 feet above the channel bottom. Revetments are assumed to be 10 feet high and 5 feet thick. A toe and 1(v):2(h) or flatter side slope is critical for stability.

Estimated revetment locations and riprap volumes are presented in Appendix C Table C-1.

MSE retaining walls may be appropriate for areas that have non-erosive bedrock extending at least 15 feet above the channel bottom. Avoid locating MSE retaining walls below the 100-year flood level or on erosive foundation soils.

A large alluvial fan on the opposite side of the river at road segment 4, stations 930 to 960, is forcing the river against the proposed road alignment. The road embankments will likely experience fluctuating riverbed levels, impinging flow, and high shear stress. To develop the conceptual level design and cost estimates, design the road profile here at least 20 feet above the channel bottom.

Channel Migration Zone Encroachment

Within the channel migration zone (CMZ) the river channel freely relocates through migration and avulsion processes. The CMZ is an area that has historically contained active channels, and is likely to contain them in the future. LIDAR aerial photography, USGS topographic mapping, and conceptual road alignment plans were used to delineate areas with low topographic relief, flood scour channels, abandoned channels, and active channels, features that define the CMZ. The unconfined reaches of the river are prone to rapid channel relocation.

The CMZ is shown on Appendix C Figures 2 through 6. Encroachments occur at stream crossings and where the proposed road is confined at the base of steep valley walls. The hydraulic study assumes that floodplain limits approximately coincide with the CMZ and that encroachments into the CMZ, outside of the floodway, do not currently experience deep, fast flowing water that cause erosion. An encroachment into the CMZ will probably experience frequent flood inundation.

Assuming the channel will eventually relocate to flow near or against the road embankment, construct the road profile above the anticipated design flood levels. To develop the conceptual level design and cost estimates, assume the road profile within the CMZ needs to at least 10 feet above the surrounding ground surface. Encroachments are assumed not to initially require scour protection.

Alluvial Fan Encroachment

Alluvial fans are fan-shaped areas at the mouth of steep gradient canyons that experience frequent flooding, stream channel relocation, sediment deposition, and debris flows. The alluvial fans shown on Appendix C Figures 2, 3, 4, and 6 were delineated using LIDAR aerial photography, USGS topographic mapping, and the conceptual road alignment plans.

Encroachments occur across alluvial fans at:

- Segment 1B, Station 120
- Segment 1C, Stations 290, 320, and 360
- Segment 3, Stations 520, 555, 610, and 710
- Segment 4, Stations 760 and 870
- Segment 5, Stations 1360, 1500, 1530

Roads constructed across alluvial fans or at the fan toes will experience frequent flooding and overtopping; sediment and debris deposition within and upstream of drainage structures; and stream channel relocation.

Cross alluvial fans at the apex. When crossing below the apex maintain the road profile above the ground surface. Avoid cuts into alluvial fans; they encourage flooding and debris deposition on the road. Appropriately sized drainage structures placed in topographic low points at the fan perimeters convey discharges during flooding and channel relocations. Riprap placed at the upslope road embankment toe controls erosion from water flowing along the base of the road fill. Constructing the road profile above the fan surface and over sizing the drainage structures extends the service life and reduces the maintenance of the road and drainage structures.

Bridge Installation

Bridge crossings are assumed for all streams with 50-year design peak discharges greater than 1000 cubic feet/minute (cfs). No stream gage station data is available for developing flood frequency analyses. Design peak discharges at the crossing sites were estimated using drainage area, precipitation, lake area, and mean January temperature based regional regression equations (USGS Report 03-4188, 2003). Drainage areas were determined using USGS quadrangle maps. Mean annual rainfall of 180 inches and mean minimum January temperature of 26 degrees Fahrenheit were obtained from mapping in USGS Report 03-4188. Some drainage basins have glacial lakes. Glaciers occupy most of the headwater valleys.

Bridge locations are shown on Appendix C Figures 1 through 6. Figure 13 shows the proposed East Fork Bradfield River crossing. Bridge locations, diameters, and 50-year design peak discharges are presented in Appendix C Table C-2. To develop the conceptual level design and cost estimates, assume spill-through abutments with 1(v):2(h) side slopes and 15-feet minimum clearance between stream bottom and bridge low chord.

Figure 13. Proposed bridge crossing.
Bedrock ridge outcrops at lower right of photo.

Large Diameter Culvert Installation

Large diameter (greater than 10 feet) culvert crossings are assumed for all streams with 50-year design peak discharges between 500 and 1000 cfs. Design peak discharges at the culvert crossing sites were estimated using the approach discussed on page 27, Bridge Installations. Drainage areas with discharges greater than 500 cfs represent the lower limit of what can be easily delineated using available USGS mapping. Because a 10-foot diameter culvert can convey 500 cfs assuming inlet control and a headwater to diameter ratio of approximately one, it was selected as the minimum culvert size to define for the study.

Large diameter culvert locations are shown on Appendix C Figures 1 through 6. Culvert locations, diameters, and 50-year design peak discharges are presented in Appendix C Table C-3. The culverts are generally located on alluvial fans and steep gradient canyon streams, and will likely experience abrasion, frequent sediment slugs, and debris flows. Debris racks or diversion structures may be appropriate for streams that experience extreme debris flow activity. To develop the conceptual level design and cost estimates, assume 15-feet difference between the road profile elevation and stream bottom.

Aquatic Organism Passage Culvert Installation

Anadromous fish species utilize a large portion of the lower basin. The Large Diameter Culvert installations discussed above appear to be on alluvial fans and steep gradient streams; the study assumes aquatic organism passage is not required at these locations. Aquatic organism passage will likely be required at many of the culvert crossings not identified in the study. To develop the conceptual level design and cost estimates, assume three 7-feet diameter culverts designed for aquatic organism passage are needed for the sloughs crossed by road Segment 1 Option A.

Minor Drainage Installation

Minor drainage installation includes culverts with diameters less than 10 feet, cross drain culverts, down drains, ditches, energy dissipaters, and ditch erosion control lining. The study assumes two 48-inch diameter culverts and ten 24-inch diameter cross drain culverts with down drains per road mile. Install riprap ditch lining on ditches steeper than 3 percent and energy dissipaters at all culvert outfalls. To develop the conceptual level design and cost estimates, assume a minor drainage cost of $80,000 per mile.

The culverts are generally located on alluvial fans and steep gradient canyon streams, and will likely experience abrasion, frequent sediment slugs, and debris flows. Aggressive ditch and culvert maintenance will be required.

Additional Studies

The hydraulic study was based on USGS topographic mapping, limited LIDAR aerial photography, low accuracy LIDAR based topography, and conceptual road alignment plans. Tidal area, floodway, CMZ, and alluvial fan delineation is not precise. No hydraulic modeling was performed for estimating flood levels and flow velocities.

As the road design evolves, additional studies are recommended:

- Determine design maximum tidal elevation and minimum road profile elevations for tidal area.
- Verify wave height and wave setup assumptions for marine and tidal areas.
- Complete hydraulic modeling for floodway encroachments and bridge crossings.
- Delineate CMZ and verify minimum road profile assumptions.
- Verify aquatic organism passage requirements.
- Delineate alluvial fans.
- Complete hydraulic design for culverts.
- Evaluate debris flow and sediment slug hazards.

The Environmental Document

The size and scope of the conceptualized project indicates to WFLHD and the cooperating agencies that a National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS) is the appropriate level of documentation.

It may be beneficial to use a separate NEPA document, most likely a Categorical Exclusion to document the rehabilitation of an abandoned forest service logging road as described in X.1.5.4. The temporary road may be utilized to access the Bradfield River valley for resource studies needed to document the EIS.

Based on previous experience with similar projects, it is estimated that a document of the scope of an EIS will cost approximately 5 percent of the total estimated project cost, and require a minimum of five years to complete. It is anticipated that the final EIS will be a "dual" U.S.-Canadian document following a basically NEPA format. The Michigan Department of Transportation (MDOT) has successfully completed such a document in cooperation with the provincial government of Ontario, so WFLHD will consult with the MDOT and the Michigan Division of FHWA for guidance on how to coordinate and prepare such a dual document that satisfies both U.S. and Canadian environmental laws and regulations. The environmental laws of both countries have many similarities in both content and procedure, so "merging" the two documents may be feasible.

Anticipated Environmental Impacts

Because the conceptual road must follow a glacial river valley and stay in relatively close proximity to the stream to achieve a constructible grade at an affordable cost, the most obvious environmental impacts will be related to water: wetlands, fish and their habitat, and water quality. Because of the remote location and its relatively pristine condition (beyond the end of the abandoned Forest Service logging road and clear cuts), wildlife habitat, riparian zones and aesthetics are resources that will also receive more attention from the resource management agencies than they would in more highly disturbed and populated settings.

Conversations with the Alaska Department of Fish and Game (ADF&G) have informed WFLHD that the Bradfield River contains all five species of salmon (Chinook, Coho, Chum, Sockeye and Pink), Steelhead, Cutthroat trout, and Dolly Varden char. The presence of salmon, trout and char designate this river as an anadromous stream. There are relatively narrow mid-summer in-water work windows in such streams that could have a significant effect on the timing of construction for structures in the water, such as riprap revetments, culverts, and bridge piers. Typical in-water work windows extend from July 15 through August 30, and some are even shorter. The ADF&G biologist did inform WFLHD, however, that there is a natural barrier (waterfall) to fish migration at approximately river mile 14 . Upstream of that waterfall, there are no anadromous fish, and hence, fewer fish-related restrictions on in-water work.

The Bradfield River is glacially fed, and, as such, runs visibly cloudy for most of the year. However, water quality regulations will require that background turbidity not be exceeded by more than a fixed percentage of that existing background turbidity. Turbidity will need to be monitored in order to comply with State and Federal water quality standards. It is assumed that Canadian water quality standards are comparable, and will also require monitoring.

It is estimated, by viewing the Bradfield River Valley terrain and extrapolating from previous projects in Southeast Alaska, that approximately 2 acres of wetlands will be impacted for each low elevation road mile constructed. This quantity is conceptual only and will be determined once the project is commenced. These wetland impacts will be concentrated at the lower elevations of the project, within the river floodplain and glacial outwash areas. The higher elevations are predominantly exposed bedrock, talus and glacial scour zones devoid of soil or vegetation. Approximately 75 acres of mostly emergent wetlands (muskeg bogs and fens, and intertidal flats) are estimated to be impacted between the head of Bradfield Canal and the U.S./Canada border. These wetlands will need to be mitigated per the requirements of the U.S. Army Corps of Engineers regulations under Section 404 of the Clean Water Act.

Environmental Access Constraints

Previous documentation (McDowell Group, Inc., 2004) demonstrates that the British Columbia portion of the conceptualized route has access constraints that begin at the headwaters of the Craig River, which since 2000 has been designated as the Craig River Headwaters Park. An area of 18,750 acres (29.3 square miles or 7500 hectares) was established to protect low elevation coastal western hemlock forest and associated ecosystems, including: fisheries values, salmon spawning and rearing habitat; grizzly bear habitat; key areas of grizzly bear/salmon interaction; and high recreational values (remote access).

The existing mineral claims within the protected area boundary, including the existing mining road at Volcano Creek, will be excluded from the protected area until such time as the claims lapse.

In the event that a road request is made, and where a reasonable review determines that no practicable alternative exists outside the protected area, then provincial British Columbia government authorities will make a decision regarding the access request. The decision will be made in consideration of the integrity of the protected area and the need for road access for mineral activities, in accordance with applicable approval processes.

The Craig River area is noted for its fisheries values, its grizzly bear habitat, key areas of grizzly/salmon interaction, and related recreational values (bear viewing opportunities). The Craig River is famous for its salmon fishing, and guides located at Bell II Camp on BC Highway 37 bring sport fishers in by helicopter.

The Lower Iskut Zone also has access constraints. This zone encompasses 30,000 acres (46.9 square miles or 12,000 hectares) of land downstream of the Craig River Headwaters Park to the confluence of the Craig and Iskut Rivers, where the Lower Stikine-Iskut Grizzly/Salmon Management Zone begins. The intent of this zone is to conserve the fisheries and habitat values of the lower Iskut River and to provide management continuity between the Middle Iskut and Lower Stikine-Iskut zones. Commercial timber harvesting is not allowed in the floodplain of the Iskut River. Mainstream road development is allowed only on one side of a valley at any one location, and, wherever possible, all infrastructure development such as aerial power lines must follow existing or planned roads.

It is safe to presume that the Canadian portion of the roadway will require numerous mitigation measures to protect salmon and grizzly bear habitat and aesthetic values, and that Canadian permits will require both timing and total footprint area restrictions as part of those mitigation measures.

Public Involvement

Because of the large area of the conceptual project itself, and even more so because of the region-wide effects of the conceptual project, the public involvement phase of the environmental documentation will be an extensive undertaking. The extent of the involvement occurs in terms of numbers of people that must be notified and allowed to comment, the distance between communities affected, and time and funds that must be invested. A major effort will be required to properly notify such a widely scattered population over such a large land area that a project is being developed, and then afford them their legal right to comment, then compile those comments and incorporate them into the document in accordance with NEPA. The cost of public involvement will be a very significant portion of the total environmental cost for the project.

Introduction

This section presents the results of a literature review of the available geological reports, observations from a helicopter reconnaissance of the conceptual route, and a review of plans and cross-sections of the proposed conceptual alignment. Conceptual design recommendations are based on an evaluation of the geotechnical considerations associated with the proposed route, including the following: muskeg sub excavation, retaining wall needs, cut and fill slope requirements, geological hazards assessment, and preliminary tunnel feasibility and cost estimates. Recommendations are intended for general route feasibility and rough quantity estimating purposes only.

A final design will require geotechnical investigation efforts commensurate with recent FHWA, AKDOT&PF, or USFS reconstruction projects in Southeast Alaska. Limited access to the project site and numerous river crossings may restrict the initial scope of these investigations to activities and observations that can be achieved using hand-operated equipment. Final drilling and test pit investigations would then need to be performed as access is constructed.

Geography

The conceptual road alignment climbs the highly dissected west flank of the Coast Mountains. Steep topography, many swift streams, heavy precipitation, and many alpine glaciers characterize the terrain. Dense forests grow in elevations of 2,500 feet or less, while low-lying alpine grasses, shrubs, and lichens inhabit higher elevations.

The first 2.5 miles of the conceptual route Segment 1 Option A follows the south margin of a broad (1.5-mile wide) tidal flat/river delta, where numerous braided stream channels cut through the silty sand and gravel deposits. Extensive areas of rich, organic surface deposits occur throughout the areas above the tidal influence. Cuts for the existing gravel road indicate that the organic surface deposits average 2-3 feet deep. Above the confluence of the East and North Forks of the Bradfield River, the floodplain narrows to a width of about 0.5 mile. The floodplain remains about this width for the next 15 miles, where the conceptual route generally follows the rugged side hills adjacent to the floodplain. Above MP 16.00, the river gradient increases significantly as the river becomes more confined by the steep terrain. From this point, the conceptual route crosses increasingly steeper, dissected terrain, with correspondingly increasing alignment grades leading to the portal of a proposed 1.5-mile long tunnel that begins at MP 21.40 and crosses through a saddle of massive granitic rock. From the northern tunnel portal, the conceptual alignment contours along the lower flank of a broad U-shaped glacial valley in a northeasterly direction, to the project terminus at the U.S./Canada border.

Geology

Regional geology is characterized as northwest trending, high-grade metamorphic rocks of diverse composition, intruded by plutonic rocks of the Coast Range batholith. Reconnaissance geologic studies of the area are mapped on a broad, regional scale, with little detail in differentiating subunits within the plutonic and metamorphic rocks. Metamorphic units are the dominant rock type along the conceptual alignment, and include gneiss, granulite, and schist. Plutonic rocks are exposed along the crest of the Coast Mountains, and are generally granitic, consisting predominantly of quartz monzonite with quartz diorite dikes. A Bradfield River mineral study identified an intermediate unit of metasedimentary rock along the conceptual alignment.[3] This intermediate unit consists of light gray to white marble and skarn along the contact with the metamorphic and plutonic units, and occurs between the elevations of 500 to 1000 feet.

Glaciation has significantly modified the landscape, forming U-shaped valleys, rounding peaks and ridges, and leaving deep deposits of till. Till deposits are the remnants of receding alpine glaciers, comprised of a mix of both metamorphic and plutonic rocks. Till deposits occur near the mouths of many tributaries of the Bradfield River. The original deposits have been reworked by the river and its tributaries, forming fluvial glacial deposits in the broad floodplain of the North Fork. The tills are predominantly gravel, but range in composition from silty fine sand to boulders, depending on the energy of the depositional environment.

Muskeg deposits, which are comprised of very soft, highly compressible organic materials, are anticipated along the entire conceptual alignment. Muskeg deposits can occur in any location, including steep, timbered hillsides. These deposits typically vary from 1 foot to over 30 feet in depth, and are very irregular and unpredictable over small distances. However, due to the well-developed drainage patterns in the steep terrain, most muskeg deposits will likely be less than 10 feet deep. The most extensive and deepest muskeg deposits are typically found at nearly flat or low lying areas adjacent to streams, as shown in Figure 14 below. Muskeg surfaces are soft and spongy due to the 6- to 12-inch thick sod mat that overlies the very soft, fibrous, organic material below, and groundwater levels that are typically near the surface of the muskeg. Roadway embankments constructed over muskeg deposits will settle, causing warped grades and severe pavement distress. The preferred method for constructing stable roadbeds is to sub excavate the muskeg and replace the excavated material with shot rock fill.

(See photo next page.)

[3] MacKevett, E.M., Jr., 1963, Geology of the North Bradfield River Iron Prospect, Southeastern Alaska, USGS Bulletin 1108-D.

Figure 14. Muskeg deposit at Station 210+50

Evaluation Of The Conceptual Alignment

A conceptual alignment was developed based on topographic information obtained through side-looking radar and aerial photography, with preferred alignments identified during the helicopter reconnaissance. The 30-mile corridor (Segments 1 Option A w/Segments 2-5) was divided into five segments for design and discussion purposes. Geotechnical considerations were evaluated for each segment, and geological hazards (debris flow channels, snow avalanche chutes, and run-out zones) were identified. Refer to Appendix D Table D-2 for hazard locations. Rough estimates of sub excavation and retaining wall quantities were developed, as summarized in Appendix D Table D-1. These evaluations are intended to provide a more accurate appraisal of the feasibility, cost, and potential problems associated with the conceptual alignment. The following sections contain detailed discussions of each segment of the conceptual alignment.

Segment 1, Option A, (Station 88+00 to 261+46)

Station 88+000 to 261+46 - Segment 1 conceptual alignment generally follows the existing gravel road alignment across the southern margin of the tidal flat/floodplain to the confluence of the East and North Forks of the Bradfield River. Silty fine sand and gravel deposits are covered with relatively thin organic soil deposits. Cuts along the existing road indicate the organic surface soil deposits are approximately 2-3 feet thick and consist mostly of forest duff and roots, as shown in Figure 15. Sub excavations are anticipated to remove the organic soils, both in the notch to widen the existing road, and where the proposed alignment deviates from the existing road.

Figure 15. Organic surface soils underlain by silty sand, 700 feet to the left of Station 214+00

The conceptual East Fork bridge crossing was shifted downstream from the washed-out log bridge crossing in order to take advantage of rock outcrops observed at the proposed abutment locations. The rock provides natural scour protection and allows spread footing foundations for the bridge abutments. The conceptual bridge location is shown in Figure 16.

(See photo next page.)

Figure 16. Downstream view of conceptual East Fork bridge crossing at Station 226+00

Segment 1, Option B (Station 10+00 to 270+00)

Station 10+00 to 140+00 – This alternative conceptual alignment is situated along the north shore of the Bradfield Canal, traversing the coastline in a northeasterly direction to the tidal flats at the mouth of the canal. At this point, the conceptual alignment turns east and follows the margins of the tidal flats. The conceptual alignment crosses the base of moderately steep, heavily forested slopes. The terrain is dissected by abundant local draws and ravines separated by rocky ridges, generally oriented perpendicular to the alignment. Proposed cuts through the ridgelines are up to 100 feet high, with 20- to 60-foot deep fills in adjacent draws. Due to the alignment's close proximity to the coastal fringe, extensive retaining walls will be required throughout the fill sections to prevent fill from spilling into the canal. Sub excavations are anticipated to remove soft, compressible soils where the roadway crosses the margins of the tidal influence.

Two of the three conceptualized bridges are located along the tidal flats near the end of the Bradfield Canal. The first two structures span a wide tidal flat near the mouth of the stream near Station 50+00. Two 100-foot structures are conceptualized, along with a 10-foot culvert. Piers will require deep foundations through the soft, compressible tidal flat sediments. The third structure crosses the relatively narrow stream channel at the mouth of the White River at Station 134+00. Abutment foundations for the conceptual 200-foot long structure will likely consist of driven piles in alluvial and glacial deposits at the west abutment, and a spread footing on shallow rock at the east abutment.

Section 140+00 to 190+00 – Tidal flats transition into a wide floodplain of braided stream channels at the mouth of the Bradfield River. Currently, the main channel of the Bradfield River flows along the northern margin of the valley, with the proposed roadway alignment following moderately rolling, well-vegetated terrain along the northern margin of the floodplain. Revetment walls are proposed where the alignment impinges upon the river channel. Minor sub excavations are anticipated where the roadway crosses shallow muskeg and soft alluvial deposits.

Section 190+00 to 270+00 – The proposed alignment turns away from the river and follows the margins of the floodplain to the proposed bridge crossing of the Bradfield River and link to the Option A alignment. The gently rolling to flat terrain is heavily forested and contains abundant muskeg deposits, predominantly along abandoned river channels. Muskeg deposits will require moderately deep sub excavations to remove the compressible organic soils. The proposed bridge crossing the Bradfield River at the end of this segment will most likely require driven pile foundations in the alluvial deposits at the west abutment and a spread footing foundation in shallow rock at the east abutment.

Segment 1, Option C

M.P. 0.00 to 8.02 - This conceptual alignment was outside the original scope of the project and no geotechnical analysis has been conducted.

Segment 2, Station 260+00 to 444+50

Section 260+00 to 340+00 – The conceptual alignment begins in one of the several rock bluffs that abruptly form the margin of the main channel of the Bradfield River, follows the east riverbank, through relatively flat terrain along the margin of the floodplain, and cuts through additional prominent rock points where they impinge upon the river channel. A full-bench rock cut would be required at the beginning of the segment, in order to avoid filling into the main river channel, which flows at the base of the high rock face. As the route transitions out of the full-bench cut from station 273+00 to 279+00, fill-side retaining walls along the river may be required to avoid encroaching on an active braided channel. Anther rock point from station 304+00 to 308+00 would require a full-bench cut up to 60 feet in height.

Conceptualized embankments crossing the floodplain will likely encounter organic surface soils (forest duff and roots), with patches of shallow muskeg of less than 5 feet deep. A standard embankment sub excavation detail that specifies removal of all soft or organic material will be required. For conceptual design purposes, the average depth of the floodplain embankment sub excavation may be estimated at 2 feet below the existing grade. It is advantageous to minimize the embankment height, because the full width of the embankment footprint requires sub excavation.

Section 340+00 to 351+00 – A broad, well-forested alluvial fan intersects the alignment at the mouth of a large U-shaped glacial valley. Materials are likely a mix of glacial and fluvial sandy gravel, cobbles and boulders. The lack of vegetation along the channel suggests that the stream is subject to high seasonal flows or debris discharges.

Section 355+00 to 369+00 – Aerial photos of this section show a poorly drained grassy area devoid of large trees, indicative of a deep muskeg deposit. The conceptual alignment skirts the eastern margin of the muskeg, which avoids the potentially deeper muskeg toward the center of the clearing. Shifting the alignment to the right, into the rocky hillside, would minimize the impacts to the wetland as well as reduce the volume of muskeg sub excavation. Along the current conceptualized alignment, muskeg deposits below the embankments are estimated at 6 to 15 feet deep.

Section 393+00 to 402+00 – The conceptual alignment generally follows a narrow swath of moderately sloping ground between the main river channel and a steep rock face. A fill-side retaining wall averaging 30 feet high, located within the scour zone of the river, is anticipated to minimize encroachment into the river channel. Typically, due to the high probability of losing a wall during a flood event, WFLHD policy discourages construction of high replacement cost retaining structures (which includes walls over 10 feet high) within the river channel.

Section 403+00 to 444+50 – Conceptual embankments crossing the floodplain will generally encounter organic surface soils (forest duff and roots), with a patch of muskeg (estimated at 5 feet deep) between stations 421+00 and 425+00. From station 434+00 on, the conceptual alignment encroaches on the edges of open water channels along the southeast margin of a muskeg deposit. A shift to the right, into a rocky slope, would minimize impacts to the wetland.

Segment 3, Station 444+50 to 737+30

Section 444+50 to 556+00 – The conceptual alignment follows the edge of the margin of the floodplain, crossing the toes of several moderately steep rock slopes which are dissected by deep, geologic structure-controlled gorges cutting perpendicular to the conceptual alignment. This terrain results in a highly irregular ground profile along the centerline, with conceptual rock cuts of up to 100 feet high. Soils are anticipated to be shallow, comprised of organic forest duff and roots overlying the rock, with a patch of muskeg (estimated at 5 feet deep) occurring to the west of the toe of the embankment between stations 455+00 and 457+00. Several retaining walls may be required where the embankments encroach upon the river channel.

Section 556+00 to 567+00 – This segment of the conceptual alignment traverses a broad, fan-shaped glacial outwash deposit at the mouth of a large U-shaped valley. Outwash deposits are anticipated to be 60 to 100 feet deep, based on the adjacent topography, and consist of predominantly granular soils and granitic boulders, according to USGS information. Cuts up to 60 feet high will be required as the roadway crosses this deposit, and conceptualized cut slopes with a ratio of 4:1 (vertical distance:horizontal distance) will need to be adjusted to a slope of 1:1.5. An alignment or grade change may also be required in order for the cut slopes to catch. In addition, the fan-shaped change in vegetation from an older forest at Station 559+00 to a younger forest at Station 564+00 indicates this area is subject to potential geologic hazards from debris flows or snow avalanches.

Section 567+00 to 737+30 – For the most part, the conceptual alignment crosses moderately sloping terrain along the margin of a broad floodplain, at times encroaching on abandoned braided stream channels and crossing intermittent muskeg deposits that are estimated to be less than 5 feet deep. Several fill-side walls may be required to retain the embankments where they spill onto the braided channels; however, specific potential wall locations were not identified because these channels are partially overgrown and abandoned by the main river, which flows on the opposite side of the nearly 1-mile wide floodplain. In some areas, cuts up to 160 feet high will be required through steep, protruding rock bluffs.

Through the section from station 673+00 to 685+00, the conceptual alignment is precariously situated between the active river channel and a steep rock cliff. A retaining wall may be needed to minimize encroachment into the river; otherwise, a full-bench cut approaching 200 feet high will be required to accommodate the roadway.

From Station 705+00 to the end of the segment, the terrain is comprised of gently rolling fluvialglacial deposits. As the conceptual alignment crosses these deposits, required cuts up to 70 feet high are designed as rock cuts at a preliminary slope of 4:1. The depth of rock through this area could vary considerably from station to station; for conceptual design purposes cut slopes over 20 feet high should be designed at an intermediate slope of 1:1, and cuts less than 20 feet should be designed at 1:1.5.

Segment 4, Station 740+00 to 1200+75

Section 740+00 to 750+00 – This segment continues along the right margin of the floodplain, beginning in a transition from gently rolling fluvialglacial deposits, passing through a short-but-steep rock bluff rising adjacent to the floodplain, and continuing onto the flank of a broad alluvial fan / glacial outwash deposit. Rock cuts of up to 150 feet high are proposed where the alignment shifts to a full-bench cut through the bluff to minimize impacts to the floodplain.

Section 750+00 to 768+00 – In this segment, the conceptual alignment crosses a broad, fan-shaped alluvial / glacial outwash deposit at the mouth of a steep canyon, passing approximately halfway between the toe and apex of the fan, and bridging a stream at Station 762+00. The younger vegetation patterns indicate that the entire fan is subject to potential geologic hazards from debris flows and snow avalanches. Conceptualized cuts are up to 40-feet high, with slopes of 4:1. For any design, all cuts through this area should be changed to maximum slopes of 1:1.5 to reflect typical cut slopes in the anticipated granular materials.

Section 768+00 to 808+00 – An extensive marshy area with potentially deep (>10 feet) muskeg deposits occurs between the active Bradfield River channel and the eastern slopes of the valley. The conceptual alignment follows the moderately sloping ground along the eastern margin of the wetlands, minimizing wetland impacts as well as avoiding the potentially deep muskeg deposits. Occasionally, the embankments spill onto the margins of the muskeg deposits; muskeg sub excavation is anticipated in those areas.

Section 808+00 to 840+00 – As conceptualized, the alignment encroaches into the main Bradfield River channel, and requires extensive fill-side retaining walls. For any design, this alignment should be shifted into the moderate-to-steep slopes on the right stream bank, to minimize encroachment. However, even with a shift, extensive fill-side retaining walls may still be required.

Section 855+00 to 873+00 – In this segment, a major tributary stream exits the mouth of a large, glacially carved valley, forming an extensive fluvialglacial fan, estimated to be over 60 feet deep, that spills into the floodplain of the Bradfield River, diverting the flow of the river around the toe of the fan. The conceptual alignment crosses near the head of the fan, requiring a major structure to span the 250-foot wide channel. Aerial photos indicate that a large muskeg deposit occurs adjacent to the conceptualized south abutment approach; however, the conceptualized 10-foot deep through-cut should remove the muskeg thereby stabilizing the roadbed. Cut slopes through this area should be adjusted to maximum slopes of 1:1.5 for any design.

Section 873+00 to 973+00 – Benched into the moderately sloping-to-rolling terrain, the conceptual alignment continues along the eastern margin of the floodplain to the first crossing of the main Bradfield River channel at Station 973+00. Cuts up to 50-feet high are conceptualized, although an anticipated alignment shift out of the active river channel and into the adjacent steep rock bluff between Stations 833+00 to 860+00 will necessitate rock cuts of up to 90 feet high, as well as an extensive fill-side wall. At isolated locations, the embankment spills onto small wetlands with relatively shallow (less than 5-feet deep) muskeg deposits. Several suspected avalanche chutes occur along the steep terrain just east of the conceptual alignment, although this alignment location appears to lie just outside the maximum extent of the run-out zones. At the proposed bridge crossing, a muskeg deposit occurs along the south abutment approach, which is expected to be removed by the conceptualized 10-to-25-foot deep through cut.

Section 975+00 to 1089+00 – In this segment, the wide floodplain narrows abruptly as the river channel transitions into an incised canyon section. The conceptualized alignment is benched into the moderate-to-steep terrain, with rock cuts of up to 120 feet high, along the western slopes of the canyon. Deep tributary stream channels cut across the thickly forested slopes at frequent intervals; many channels are also avalanche chutes. Retaining walls are anticipated where the toes of embankments filling into these tributary channels encroach onto the main river channel.

Vegetation patterns indicate that the conceptual alignment crosses muskeg deposits on several relatively flat terraces. Muskeg depths at these terrace deposits may be relatively deep (5 to 10 feet), as indicated by the poorly defined drainage patterns and large vertical separation from the main river channel. As conceptualized, some deposits will be excavated with cuts; others will require sub excavation.

Section 1090+00 to 1129+00 – Two closely spaced bridges are conceptualized along this segment where the river makes a 90-degree turn along the angular margins of a broad terrace. The Station 1090+00 bridge grade is over 90 feet above the stream, requiring a multi-span structure or, alternatively, MSE wall abutments. Between bridges, the alignment makes a through-cut of up to 50 feet deep across the gently rolling terrace terrain. Vegetation patterns with sparse forest indicate either potential muskeg deposits or shallow rock throughout the terrace. In the absence of significant standing water, shallow rock is most likely. Beyond the bridge at Station 1106+00, the sparse forest vegetation pattern continues. As the majority of the conceptual alignment through this area is a cut, no sub excavation of muskeg is anticipated.

Section 1129+00 to 1199+00 – Continuing along the toe of the western face of the valley, the conceptual alignment increases grade as it begins the ascent toward the southern conceptualized tunnel portal. The conceptual alignment then begins to deviate from the river channel as it climbs through varied terrain ranging from steep rock slopes with abundant avalanche chutes and avalanche run-out zones to rounded rock bluffs, as shown in Figure 17.

Figure 17. View of the glacial valley east of the conceptual alignment from Station 1200+00

Deep, V-shaped chutes, treeless expanses, and tree and rock debris indicate that the avalanche hazard along this portion of the conceptual alignment is very high. Avalanches occur in both confined chutes and over broad release zones. The zones identified from the aerial photos are listed in Appendix D Geological Hazards Table D-2. A more detailed study of avalanche hazard is recommended, as the location and extent of chutes and release zones will have significant impacts on the all-season use of a road in this location. Even if travel is restricted to seasonal use only, removable or avalanche resistant structures will need to be considered for signs and guardrails.

Segment 5, Station 1200+00 to 1538+27

Section 1200+00 to 1221+00 – This segment begins by crossing a wide and deep canyon. The first 300 feet span an active snow avalanche run-out zone. Currently, a conceptualized large, deep embankment with a12-foot culvert will span this canyon. The embankment across this area could be constructed from tunnel excavation spoils. After the canyon, the conceptual alignment crosses rolling terrain with rock knobs and two small muskeg deposits before it enters into the conceptualized south tunnel portal excavation, as shown in Figure 18.

Figure 18. View toward south tunnel portal location from Station 1200+00

Section 1221+00 to 1300+00 (TUNNEL) – The conceptualized tunnel crosses the summit of the Coast Mountains, leaving the Bradfield River drainage and entering the South Fork of the Craig River drainage. Aerial reconnaissance observations indicate that the conceptualized southern portal appears to be situated in massive granitic rock that has been polished into rounded knobs by glaciers. Streams have dissected the rock along linear, structurally controlled joints and fractures that are clearly visible in the aerial photos. These structural features are generally trending parallel and perpendicular to the conceptual tunnel alignment. Additional field investigations should be performed in order to determine the geometric relations of the structural joints and fractures to the conceptual tunnel alignment. The most noticeable structural feature parallels the conceptual tunnel alignment 150 to 200 feet east from the southern portal to Station 1255+00.

From Station 1274+00 to the northern portal of the conceptual tunnel, several deeply incised avalanche chutes cut sub-perpendicular across the conceptual tunnel alignment. These chutes formed in weaker rock zones along the joints and fractures that undoubtedly intercept the conceptual tunnel alignment at depth. Geologic maps indicate the conceptual northern portal is near the contact with the granitic rocks and the metamorphic rocks. The irregular topography and boulder talus debris visible in the aerial photo indicate that the rock conditions at this portal location may be more fractured or sheared along this contact.

Section 1300+00 to 1375+00 – The conceptual northern portal exits on the northwest facing slope of the broad, U-shaped, glacially carved valley of the South Fork of the Craig River. The conceptual alignment follows the river as it flows north and east into Canada. From the conceptual northern portal onward, the stunted vegetation indicates that the conceptual alignment crosses a continuous avalanche run-out zone covering the lower apron of talus deposits along the toe of the steep ridges to the east. Avalanches apparently release in sheet-type masses from the cliffs between the canyons, and also exit through chutes cut into the steep ridges to the east. Fresh deposits on the alluvial fans indicate these areas also produce debris flows.

Section 1375+00 to 1430+00 – As the conceptual alignment descends the east flank of the valley, the terrain transitions from steep, rocky slopes to moderate, densely forested slopes. The conceptual alignment then reaches the river valley and parallels the southeastern stream bank. Preliminary conceptualization indicates that a large embankment section, from Station 1385+00 to Station 1410+00, encroaches into the floodplain. It appears that the impacts to the flood plain could be minimized by shifting the conceptual alignment into the moderately sloped terrain to the right. A steep rock knoll adjacent to the Craig River channel at Station 1418+00 to 1427+00 will require rock cuts up to 140 feet in height.

Section 1430+00 to 1538+27 (Project Terminus) – The Craig River curves to the east as it flows to the U.S./Canada border. The terrain transitions to rolling forested ridges that separate relatively flat, open areas that presumably have moderately deep (less than 5 feet) muskeg deposits. The conceptual alignment generally stays well away from the active river channel as it closely follows the margins of the valley floor.

Conceptual Design Recommendations

Earthwork

General – For design purposes, anticipated materials may be classified into two categories: rock and soils. Soils include glacial outwash, alluvial deposits, muskeg, and forest duff topsoil. With the possible exception of some of the cleaner glacial and alluvial fan deposits, soils will be moisture sensitive, and therefore, unsuitable for embankment construction in the region's wet climate. Soils will generally be easily disturbed and require sub excavation to a depth of 2 feet below sub grade in order to construct a working base of rock borrow for construction equipment support. Roadway embankments constructed over organic deposits will settle, causing warped grades and severe pavement distress. Muskeg and organic surface soils are anticipated to be relatively shallow (less than 5 feet). The method of choice for construction of stable roadbeds is to remove the muskeg and replace the excavated material with shot rock fill. Sub excavation locations and estimated depths are listed in Appendix D, Table D-1.

Where soils can be identified, cut slopes should be designed at a flatter slope to more accurately reflect the quantities of materials anticipated to be removed. Cut slopes in soils are at the highest risk of erosion from the time of completion through the first season of rains, before vegetation can be established. Surface erosion concerns dictate that slopes should be designed to minimize the risk of erosion. Erosion control is generally accomplished during slope design by laying the slope back as flat as is practical and incorporating site specific erosion control details such as the following:

- cut-off drains at the top of slopes
- rock blankets in seepage areas
- rip rap along small drainage channels.

Generally, the recommended cut slope in muskeg, alluvial, and glacial deposits is 1:2, vertical-to -horizontal distance (1V:2H). Maximum cut slopes of up to 1:1.5 may be constructed in dense gravel deposits, provided adequate erosion control measures are incorporated into the design. During construction, cut slope erosion may be further reduced by minimizing the disturbance of the in-situ material along the finished slope surface during excavation. Once wet soils (and especially organic soils) are disturbed during excavation, they behave as thick fluids that tend to flow. Glacial deposits will usually be saturated when excavated.

The stability of natural rock outcrops is generally structurally controlled. Steep faces occur along near-vertical joints and fractures. Natural outcrops are usually at slopes of 4V:1H or steeper, corresponding to the orientation of the primary joints and fractures. For preliminary design purposes, generic cut slopes in rock should be designed at 4V:1H. Rockfall protection may be provided by incorporating standard rockfall ditch designs as described below.

Glaciation and differential weathering produces an undulating rock surface that is covered with variable depths of overburden soils. Rock excavation during previous road construction projects in Southeast Alaska has been subject to quantity adjustments due to highly variable rock surfaces and rock weathering depth. Final design will most likely incorporate compound cut slope recommendations based on conditions encountered during the geotechnical explorations, and extrapolated beyond and between the exploration locations.

Fill slopes will be constructed of rock embankment. Maximum fill slopes of 1:1.5 are recommended. Typically, unsuitable material (organic soils, fine-grained alluvial soils, and excavated topsoil and glacial outwash) is wasted along the outside edge of finished fill slopes and in designated waste areas. Rock encountered throughout the project is anticipated to be suitable for embankment construction. A swell factor of 1.3 for rock excavation from in-place to embankment quantity is recommended.

Retaining Walls – Retaining walls are anticipated where the conceptual roadway embankments encroach into the stream channel. MSE retaining walls would be the most likely choice in this remote area. Reinforcement elements may consist of either welded wire or geogrid. Various wall facings ranging from welded wire to simulated masonry stone are available. Estimated retaining wall locations and wall quantities are provided in Appendix D, Table D-1.

Geological Hazards – Potential geological hazards identified along the conceptual alignment include debris flows and snow avalanches. Debris flows are fast-moving events that usually occur during heavy precipitation and are confined to stream channels of alluvial fans. Avalanches are most active during mid-to-late winter.

Avalanches will impact the road opening, maintenance, guardrail, and stream crossing structures. The risk from a particular hazard depends on the following:

- The type of the hazard
- The size of the hazard
- The frequency of the hazard
- The probability of occurrence
- The resource that the hazard affects

A detailed assessment of the risks associated with these hazards is beyond the scope of this report. Areas subject to debris flow and snow avalanche hazards are listed in Appendix D, Table D-2.

Rockfall Ditches

Rockfall ditch design will significantly impact the volume of rock excavation and the associated cost of this project. Rockfall ditch design recommendations presented in this report are based on the latest design recommendations presented in the Oregon Department of Transportation (ODOT) "Rockfall Catchment Area Design Guide". This design incorporates an economic analysis of ditch width and fore slope to determine the design percent of rocks retained, combined with a graphical analysis to generate a design table of standard ditch widths for a range of cut heights.

The economic analysis, shown in Appendix D, indicates the most effective rockfall design for this project is to design for 90 percent rockfall catchment utilizing a ditch with a 1V:4H fore slope. This catchment criterion was combined with the ODOT design charts to determine the catchment width for a range of cut heights. Rockfall ditch width recommendations are presented in Appendix D, Design Charts.

Geotechnical Investigations

General - The scope of future geotechnical investigations would include surface reconnaissance and subsurface explorations along the proposed alignment to characterize the conditions, define the limits and depths of surface organic soils, identify potential rock borrow and aggregate sources, and provide recommendations for roadbed preparation, cut and fill slope angles, embankment construction, retaining wall design, erosion control, and bridge foundations. Typically, subsurface investigations in Southeast Alaska involve excavating test pits at 100-foot intervals with hydraulic excavators. Highly variable depths of surface soils warrant the closely spaced explorations. Bridge sites and larger cuts will require borings. Helicopter-lifted equipment and crews will be required at the remote bridge locations.

Material Sources – Rocks found along the conceptual alignment will generally be excellent road building materials. Visual observation of the assemblage of different rock types in the gravel near the mouth of the Bradfield River indicate a variety of hard metamorphic gneiss and igneous granitic rock fragments. These rock types should make excellent base and pavement aggregate, whether extracted from gravel deposits or from hard rock outcrops.

Parsons Brinckerhoff, in association with Lachel Felice & Associates, were retained by the Federal Highway Administration – Western Federal Lands Division, to develop a conceptual design and construction cost estimate for the Bradfield Road Tunnel in southeast Alaska.

The Bradfield Road Tunnel is part of a conceptual study for a highway corridor that would connect Wrangell and Ketchikan, Alaska with British Columbia. The study area is east of Wrangell generally paralleling the North Fork of the Bradfield River. The tunnel is located beneath a mountain pass dividing the watershed between the North Fork of the Bradfield River and the South Fork of the Craig River. The tunnel will be approximately 8000 feet in length through mixed metamorphic and igneous rock types.

The remote location, combined with the severe winter weather dictate the necessity for a construction operation supported by on-site self sufficient camp facilities, providing all necessary facilities and services within the tunnel construction contract. In addition to these basic guidelines, there were a set of mutually agreed boundary conditions and assumptions established to govern the development of the conceptual design and cost estimate.

The study was required to address two tunnel options, both a twin tunnel uni-directional configuration, and a single tunnel bi-directional configuration. Due to the relatively long length, it was considered of utmost importance to develop designs and cost estimates that reflected all appropriate regulatory requirements for fire and life safety considerations.

The ventilation strategy for each tunnel option is substantially different. The single tunnel bidirectional traffic option requires removing smoke at the incident site. However, due to the remote location, it is unlikely that there will be a tunnel control center set up with emergency response teams to respond to emergency situations in the tunnel in a timely manner. In order to account for the absence of such emergency response teams, the ventilation system must be considerably oversized to account for this uncertainty.

The twin tunnel unidirectional traffic allows the use of longitudinal ventilation. The primary advantage of this method is that the fire location does not have to be precisely known. The ventilation airflow just stops smoke from spreading upstream. For traffic protection and fire smoke protection, the twin unidirectional tunnels are considered to provide a more satisfactory solution than the bidirectional traffic option.

Considering these project guidelines, the following conceptual construction costs were developed. The costs presented include no portal area earthworks, since these costs are addressed in the highway cost estimate. The costs presented include no contingency value, since the overall project will have a 25% global contingency applied to all construction costs, which will include the tunnel construction costs.

Tunnel Narrative taken from “Bradfield River Road Project Tunnel Feasibility & Cost Estimates Draft Revision 0” by Parsons Brincerhoff in Association with Lachel Felice & Associates, October 15, 2004

Table 3. Estimated Tunnel Cost Consideration

	Option 1 Twin Tunnel	Option 2 Single Tunnel
Total Tunnel Cost w/o Contingency($)	73,200,000	92,400,000
Tunnel Unit Cost w/o Contingency* ($/lf)	9,150	11,550

* Assumes tunnel length of 8000 linear feet

APPENDICES

Appendix A. Conceptual Design Plans

Appendix B. Cost Estimates

Appendix C. Hydraulic Tables & Maps

Appendix D. Geotechnical Tables

Appendix E. Tunnel Report under separate cover.
See *"Bradfield River Road Project Tunnel Feasibility & Cost Estimates FINAL REPORT*, November 30, 2004" prepared by Parsons Brinckerhoff in association with Lachel Felice & Associates